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de Vrieze, Ron

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The development of a theoretical framework to balance different stakeholder interests in order to improve school building design in the Netherlands

Ron de Vrieze

Colophon

The research institutions are: the Center for Energy and Environmental Sciences (IVEM), University of Groningen; and, the Research Centre for Built Environment NoorderRuimte and the Centre of Expertise Entrance of the Hanze University of Applied Sciences.

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Ronald de Vrieze

born on 12 February 1963
in Onstwedde

Supervisor
Prof. H.C. Moll

Co-supervisor
Prof. M.A.R. Oostra

Assessment Committee
Prof. G. de Roo
Prof. J.T.A. Bressers
Prof. J.W.F. Wamelink

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‘Some problems are so complex that you

have to be highly intelligent and well informed

just to be undecided about them.’

- Laurence J. Peter -

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GENERAL INTRODUCTION

The development of a theoretical framework that balances different stakeholder interests to improve primary school building design in the Netherlands

1.1. Introduction to the current state of Dutch primary school design

Current Dutch primary school buildings do not guarantee good school building performances. New school buildings do not perform much better than existing school buildings, although improvements in general have been observed since 2006 (Oberon 2012). Every new school building design seems to be a new challenge full of construction and design experiments. The literature reports a variety of persistent problems related to technical design and construction, disappointing sustainability performance and a lack of school building flexibility, which does not anticipate future changes (e.g. Dekker et al. 2017; KIEN 2015; RVO 2014; Pol 2009; Rodermond, Wallagh & Leun 2009; AL 2008). According to former national architect Ms Van der Pol, current problems are a result of different interests: school management boards lack the experience to act as a professional client, outdated programmes of requirements and legislative rules are used in practice, the split incentives of municipalities and school board budgets cause different responsibilities and a lack of willingness to share knowledge within the AEC sector (Pol 2009). According to the Dutch Council for Primary Schools, the POraad, the current old primary school building stock is also very poor in terms of its functionality, energy consumption, durability and technical condition (Tenkink 2016). A third of all school leaders state that the fit between their school building and the teaching programme is moderate to poor or even very poor (Dekker et al. 2017). The overdue maintenance will not be eliminated within the current system for a period of seventy years (Tenkink 2016). Some billions of euros are required to address the Dutch primary school building problems (Oberon 2012). According to the Netherlands Enterprise Agency RVO (2014) 'a break with the past is the only way to achieve a structural improvement of sustainable school building in the Netherlands'.

Dutch primary school buildings and their layouts have not changed for decades. Architectural design visions led to the implementation of new types of school buildings in the past, but the function and layout of school buildings did not change considerably. Basically, the layout consists of a number of classrooms and ancillary rooms based on the number of pupils. These rooms frequently lead to overheating or to children becoming overwhelmed by all the sensory stimuli. Education itself has changed considerably (Herzberger 2008). Herzberger (2008) states that designers of school buildings have never improved their designs of learning environments and that they have been left to do so for too long (Herzberger 2008). Although educational requirements should also always lead to changing learning spaces, the school building designs do not suit end-users' interests and specific requirements well. It remains unclear which requirements are exactly needed and why these requirements are so difficult to determine (e.g. Rodermond, Wallagh & Leun 2009). One of the problems seems to be that school management boards in general are not experienced enough to take on the client role during decision-making (e.g. Pol 2009; Rodermond, Wallagh & Leun 2009). The Dutch architectural organization BNA investigated designs of recently built schools following many complaints about the designs. Although this organization did not publish their results in full, it is clear that they concern its own views of school building design (BNA 2011). There is no clear agreement of what the end-users' interest characteristics exactly are. Although the architecture, engineering and construction (AEC) sector blamed the inexperienced clients for not stating the functional educational requirements well enough (Rodermond, Wallagh & Leun 2009) and new evolving design criteria were established by the foundation RuimteOK to help school management boards define end-users' subjective and objective requirements (RuimteOK 2014/2017).

Not only do these problems seem to cause unwanted design effects, stakeholders from the engineering and construction industry are associated with school building design mismatches and failing construction processes. Emeritus Professor De Ridder of the Delft University of Technology, who was involved as Integrated Design chair of construction information and processes, stated that construction is unable to learn from and to reflect upon the failures, and the construction sector is still a nightmare (in Doodeman 2017). According to Peek (2018), it is to be expected that commonly used tender methods in the entire AEC industry will fail to deliver good school buildings within the current economic conjuncture due to too small budgets and the procedures applied (Peek 2018). Van Zandwijk (2018) is of the opinion that this may lead to a complete stop of the construction of new schools. This persistent problematic situation and its roots that cause poor indoor air quality, layouts that are inflexible and unable to adapt future changes, poor sustainability performance and construction industry's internal organization problems are urgent and relevant to understanding how school building design can be improved.

Although the Dutch situation has its own history, the results may also be useful to other countries. The Dutch education system is regarded as one of the best systems in the world (OECD, 2016a), which makes it particularly interesting to investigate why school buildings perform so poorly in a country with education of such high quality. In general, the impediments to improving school designs can also be identified in other Western countries (e.g. Germany, the United Kingdom and Belgium) (Oberon 2012). For example, Istance (2011) states as one of the conclusions of the International Study of Innovative Learning Environments at the Centre for Educational Research and Innovation (CERI) that there is a 'great disconnect between policy and practice'. The current traditional school design establishment ignores the call for integrated school building design, fails to understand current educational visions and is unable to translate the visions into material spaces (Mumovic 2015). Experts of school building design, including Professor Heppell, hope that 'the emerging paradigm will translate into improved learning spaces and influence future architectural design' (21st Century 2013). Trends, such as personal learning environments and the development of smart intelligent building technology, predict rapid changes in the very near future for building construction methods, which will further increase the design complexity the world over (e.g. Van Wetering & Desain 2013; Van Wetering 2016; OECD 2015; OECD 2016b; Johnson, Adams & Cummins 2012; Education-2025 2015). To understand the broader characteristics of primary school building design over a long period of time, the expected future changes rapidly influence the spatial, structural and service strategies of school building. The ability to adapt to future changes of learning environments and the flexibility needed on a daily basis require new design characteristics. To frame the research and understand the complexity of Dutch primary school building design, a better understanding of the historical educational policy background and the time-related physical school building design consequences are required.

1.2. Historical background

About a hundred years ago, school building designs were based on empirical research, which determined the basic primary school building requirements. At that time, high ceilings provided air space with natural ventilation opportunities and high window frames allowed daylight to enter the classrooms. High windowsills ensured that pupils did not get distracted by pedestrians and classrooms had wall charts with, for example, illustrations of natural views (see Brasters, Grosvenor & del Mar del Pozo Andres 2011). The whole school building design seemed to focus on structure and certainty by putting pupils in classrooms that made maximum concentration possible.

From the 1960s onwards, the types of school buildings changed. A variety of new design characteristics, such as flat roofs, low ceilings with large windows and low windowsills, new classroom furniture in different arrangements and surfaces made of artificial materials, replaced the old design characteristics by introducing new architectural modern design elements. New school building designs were socially embedded into new urban residences. Empirical designs, established in the early days, were increasingly replaced by theoretical, calculated physical values and legislation rules. However, new modern school building types and compilations made of newly available construction products made it also increasingly difficult to oversee the performance consequences.

In the 1980s, a new funding scheme for Dutch school housing and primary education led to the introduction of normative budgets: the LONDO system. If every school had the same educational standards and standardized conditions, it would theoretically lead to standard payments for the establishment of new schools and for maintenance and operational costs, and it generated room for more design variety from a standard base of minimal facilities. In practice however this approach actually worsened issues of overdue maintenance. Cutbacks in budgets further increased overdue maintenance levels of school buildings. This also led to an increasingly large number of complaints, and obstructed the execution of new educational visions, especially from a physical perspective. For example, school designs from this period lack the flexibility to create spaces throughout the school where pupils can play and learn in groups or individually confirm the new educational visions. The LONDO system increasingly became a political instrument that stood between educational visions and school building quality visions and due to the continuing budget cuts, as it turned out later, it left school boards with an increasing lack of financial means for operation and maintenance (Bogaerdt 2014).

In the frugal 1990s, the government became more and more critical about honouring many municipal requests for funding of large-scale maintenance, renovation and new construction, which also meant a further increase in the backlog of daily, preventive and technical maintenance. In the late 1990s, the government decentralized primary school building accommodations. Responsibility was handed over to the municipalities, which elaborated on an integrated housing policy for new social institutional buildings. The municipalities were allowed to decide how to spend the total funds each year, which included the construction of new school buildings. Because of educational and demographical changes, resulting from the ongoing move of people to cities, the establishment of new community schools or multifunctional accommodations (MFAs) became a hype for many municipalities, which en masse proceeded to build an MFA in one of the central places or villages in the municipality. The old, smaller schools in the small villages were closed or demolished. A variety of welfare institutions, such as libraries, childcare and preschool education organizations, were accommodated in these new MFA buildings. With the construction of MFAs, the municipalities tried to solve the maintenance backlog of many other buildings.

Following a period of building many new MFAs, it was concluded that these MFAs, which were sometimes just community schools, did not meet end-user requirements very well, in particular those of children. A lot of building design failures were noted after the large new MFAs opened their doors. The question of whether such new buildings added value remains unclear. The MFAs seemed to be too difficult to manage and there was no proof of added value for educational purposes (Oberon 2012). The success of realizing a good MFA design and technical building construction, through the increasing complexity of requirement programmes, also depends on the role of board members, the competences of officials, the opportunism of advisers, architects and school management etc. (e.g. AL 2008). The new buildings often exhibit many functional and technical defects and the research institute Oberon (2012) advised to realize smaller, more manageable so-called Integrated Child Centers (IKCs).

1.3. Current urgency to improve primary school building design

Current attempts to incorporate drivers for change seem to fail. This persistent situation of physical school building design problems ultimately puts society as a whole in a lock-in situation. None of the attempts at changing this poor performing school building quality ever led to better school building performance or affected the general educational performance, and the end-users in particular, in addition to the AEC industry stakeholders and society. New teaching trends forecast far-reaching new educational opportunities and visons, which require new school building designs to adapt to the rapid changes expected. Several studies failed to demonstrate any added value for the children’s development, where added value is defined as achieving higher scores in cognitive and social-emotional domains (Verheijke, 2014).

Although the AEC industry has always based its focus on financial, political and technical factors to improve the building quality in general, it has not resulted in improvements because other factors, for example environmental and sociological factors, still dominate. The sector has for a long time called for the incorporation of more human factors. However, the AEC sector seems to be unable to substantially improve the soft skills in the design and construction process. Rodermond, Wallagh & Leun (2009) suggested that the complexity of the problems is caused by a lack of integration of disciplines within the sector. The foundation for electrotechnical installation KIEN, besides stating that solutions should be found through integrated approaches including all actors involved, also stated that the AEC industry is a too dominant conventional leader with its own technical and financial interests in the construction of schools (KIEN 2015). RVO referred to fragmented interests as one of the causes and to the organization of the AEC sector, which has no clear responsibilities and that consequently leads to mistrust among all stakeholders (RVO 2014). Subjective and objective reasons are involved here.

Although global environmental circumstances necessitate a huge priority for circular approaches of construction elements and materials, as well as for a reduction in carbon emissions in general a method to achieve the goals is lacking. Methods to support the attention for indoor climate quality and energy performance led to extra subsidies (Greendealscholen 2018), but substantial improvements are still lacking in practice. Whilst waiting for future policy plans, many school buildings still do not have any insulation. Obviously, current school building address sustainable development issues, whereby the designs have been influenced by drivers for change; however, some new drivers for change may be required.

1.4. Present drivers for change

Political and economic factors affected the school building performance through decreasing budgets for managing existing and new school building in the past. At present, new policy advises municipalities to increase the budgets for new schools by 40% (see VNG 2018). Van Zandwijk, project manager of the Dutch foundation RuimteOK for school building and childcare advice, stated that only increasing the budget does not guarantee better school building performance (in Peek 2018). According to Van Zandwijk (in Peek 2018), it remains unclear why the school building problems, including those in new school buildings, are not yet resolved. Besides the political and financial factors, the AEC industry attempts to reduce the building construction design failures and to increase the functional performance by introducing new techniques that allow for more flexible school building. However, this does not lead to substantial improvements either. For example, KIEN stated: ‘a solution to avoid the failures cannot be based on technology alone; it should be part of integrated approaches of all actors involved’ (KIEN 2015).

1.5. New drivers for change

Factors specifically related to economic, political and technical measurements to improve school building quality failed significantly. But there are still other factors to be considered. Reducing the problems by means of new politics alone (e.g. inclusive education, MFAs), increasing budgets and adding more technological instruments (e.g. digitizing the construction sector), does not automatically appear to lead to improvements. De Ridder (2017) stated that a solution should come from other industries: ‘it is all about dynamic, digital, conceptual models with which the construction finally enters a new era and which has all the algorithms’ (in Doodeman 2017). Social, environmental and design process-related factors, such as design ambitions taking into account future changes, are currently being identified as new drivers for change. A Dutch action team tasked with the innovation of the construction sector highlighted some factors to improve the building construction quality in general by introducing new themes in the TUD/CPI report *Routekaart Innovatieakkoord Bouw* (Geraedts et al. 2014): (1) the position of end-users should become more central into the design process; (2) circular approaches for material applications and renewable energy should receive more attention; and (3) buildings should become more flexible and adaptable to future changes. The Dutch building construction sector agenda defined a new school building programme to improve in particular the indoor climate quality and sustainability performance (Bouwagenda 2017). Referring to the Dutch AEC industry sector, environmental and sociological/educational factors should be more prioritized than ever before.

1.6. Complexity

The aforementioned institutional studies suggest that school building design problems are caused by a variety of stakeholder interest characteristics. A system analysis of the poorly understood relationships and interrelationships should cover psychological intra- and intersubjective behavioural pattern roles from the AEC sector stakeholders involved, end-users, school management boards and society, as well as intra- and inter-objective interests. The complexity of the problems and system/subsystem relationships between all these stakeholder interest characteristics and their individual and collective perspectives and behavioural patterns suggest that the origin of current persistent problems should be studied from intra- and intersubjective interests on the one hand and from intra- and inter-objective interests on the other. These different interest perspectives of subjective and objective requirements relate to the individual and collective experiences of physical school building design, to its multi-level problems and to the more rational objective requirements, such as building construction elements and installations. The different interest groups should be analysed separately as subsystems, before all interests can be integrated. To gain a better understanding of the problems, a systems thinking-based method was launched to analyse the physical building problems caused by balancing the different interest characteristics and behaviour patterns more specifically. To understand the complexity caused by unknown changes and rational and non-rational patterns, an interdisciplinary research approach is justified.

A system analysis should focus on producing an overview of the origin of the persistent problems, on stakeholders' different interests and stakeholders' relationships with the physical learning environments. Considering the aforementioned problems, their persistence can be defined by the occurrence of many causes and effects: solving one problem can lead to the generation of a new one, disagreements between facts and values, inseparable interwoven problems, multi-level influences and a lot of uncertainty. Incorporation of new drivers for change requires these different interests and characteristics to be distinguished first from an individual and a collective point of view, followed by finding out how these relate to subjective and objective interests. These interest characteristics appear to be a mixture of multi-level subjective and objective perspectives of looking at the problems. Associated terms such as desires, wishes and wants, needs, ambitions, requirements, laws and legislation illustrate how interests can be expressed generally. Another reason for a systemic approach is these interwoven interests in rapidly changing physical school building design (e.g. new technology, new school visions). Since the problems relate to different views and contradictory solutions, multilevel-related conflicts, a lack of research data, political and economic constraints and resistance to change etc., the complexity has a persistent nature.

1.7. Research question

The aim of the research is to understand the complexity 1) to improve the design quality by delivering a) a theoretical framework and b) instruments and guidelines that enable more understanding of the design process complexity, and 2) to balance the different interests. Therefore, four studies have been established that focus on recognizing underlying behavioural patterns and the interest characteristic scales and balance. The structure of the study is based on a three-way study of the new drivers for change through the themes of sociological drivers, environmental drivers and design process-related drivers. A system analysis which includes a cause-effect study, led to a three-way sub-study of social/educational interests, environmental scales interests and AEC industry design process interests. The research outcomes offer a new heuristic design, which delivers different sets of instruments and guidelines for practical application. The research question of this thesis is:

Main question:

'how to improve Dutch primary school building design from an integrated perspective of interests?'

1.8. System analysis of interests

First, a problem analysis is required to unravel the problem complexity of different interest characteristics. The problem analysis is the part of the system analysis used to understand the system complexity and scale factors to achieve school building design improvements and to find the balance between the different interest characteristics. In this process the new drivers for change of social/educational, environmental and design process-related interests, such as from the AEC industry, should be better balanced with business, politics and technical growth. A system analysis also helps to understand this complexity of multi-level social/educational interests and relationships with the physical environment, stakeholders' interests and rapid global changes. Taking into account the complexity and scales of the problems, the relationship with subjective and objective interests needs to be better understood. This approach prompted a multi-level study into the relationship between subjective interests and inter-objective sustainable development issues.
The system analysis of interests provides new instruments to structure and to integrate these different interests, their interactions and their relationship with the objective and subjective influencing factors. Therefore, the interests should be considered from new drivers for change perspectives: a social/educational perspective, an environmental perspective and the AEC sector school building design perspective. This incorporates all types of interest characteristics and their relationships with the present system-based drivers of economic, political

and technical interests. Therefore, the relationship between the three new drivers and the persistent problems should be considered more closely and be based on their interests and characteristics to find out which instruments and guidelines they should exactly generate.

1.8.1. The modular approach

The social/educational interests vary between end-users' interests (e.g. pupils, teachers), school management boards' interest and societal interests (e.g. a school building near to local residents). Policy legislation and ambitions constrain the design boundaries by sober and efficient school building design and minimal requirements for educational visions and do not guarantee good learning environments from an end-user's ambition perspective. Another problem is that end-users cannot describe their 'wishes and wants' well. Therefore, an instrument has to be developed that separates the interest characteristics of individual end-users, generic end-users and society in school building design. In addition, a method should also generate insights into how to mutually weigh the educational interests. Furthermore, a method should generate the general design quality indicators for end-users from a generic point of view, in addition to the specific individual and societal frames of interest characteristics. The social/educational interests have to be studied at multiple levels to balance the different perspectives.

1.8.2. Environmental interests

Society faces difficult challenges that emphasize the value of our liveability and environmental values by considering a good balance between ecosystems and social system relationships. Different environmental scales in general affect the built environment scales such as communities, and in many cases also school buildings, from a sustainable development meso-system point of view. For example, Dutch politicians have introduced a new policy that strives to achieve a circular economy in the Netherlands by 2050. Although some initiatives have already been initiated to achieve this aim, it demands a good balance between, on the one hand, knowledge of how slow environmental and sociological changes influence our world and, on the other, their relationship with rapidly changing political, economic and technological influences. It ultimately relates to the school building decision-making process.

1.8.3. AEC industry interests

The AEC industry includes the entire building construction chain of stakeholders, such as architects, contractors, advisors and product manufacturers. They all have to deal with the different interest characteristics in school building, global changes and increasing systems complexity. It includes the interest characteristics of end-users, school boards and society as well as the AEC industry's own subjective and objective interest characteristics. The AEC industry has to deal with major fragmentation of responsibilities within regular organizational processes whilst current linear approaches of school building processes still regularly conflict with, for example, architectural design and contractors' responsibilities. The AEC industry process-related problems of different interest characteristics complete the complexity of school building design by seemingly too little focus on its own sector-based innovations. The linear AEC organizational process has to be studied to balance the stakeholder interests mutually and in relation to the social and environmental system scales. From this point of view of different interest characteristics, three school building interest clusters can be identified as separate multi-level interrelated dimensions (see Figure 1.1.).

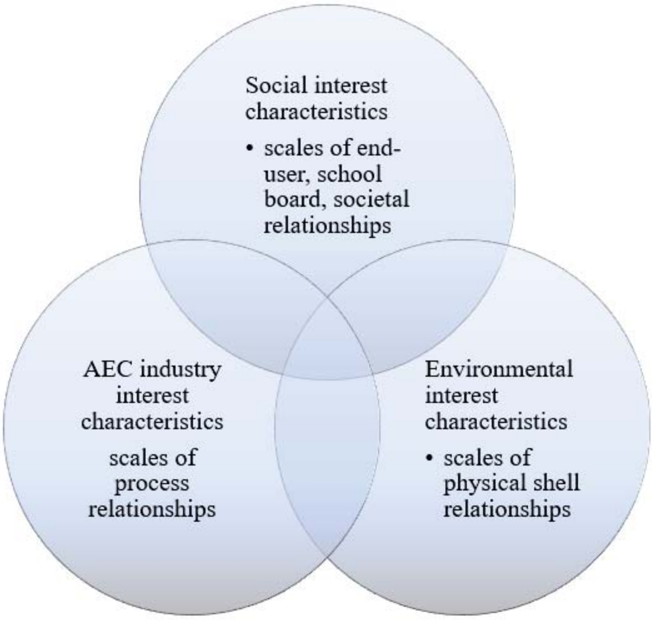

Figure 1.1. Three interrelated multi-level dimensions.

1.9. Research methodology

The three multi-level drivers for change dimensions interrelate the multi-level factors and interest characteristics. These dimensions are studied separately as three subsystems. The cause of the physical building problems and the relationship with the different subjective and objective interests will be investigated by means of a literature study. The hypothesis is that all persistent and complex physical building problems are related to underlying unconscious patterns of human behaviour and emotions. A system analysis of all stakeholder interests should therefore incorporate interdisciplinary sciences, such as social psychology, positive psychology, motivation theories, emotion theories and child development theories and how these relate to school building design and processes. This interdisciplinary approach also needs to incorporate the relationship between social disciplines and environmental sciences/sustainable development (e.g. sociological ecology). To balance the present economic, political and technical factors with the environmental, social/educational and school building design stakeholders' new drivers for change, more interdisciplinary knowledge is required.

The system analysis is followed by a synthesis in which all separate subsystems of clustered interests are interrelated into a framework that offers a method that balances all intra- and intersubjective with objective interests and that relates the different problem scales to all stakeholder interest characteristics. The problem causes are related to subjective individual behavioural patterns and interests from AEC industry stakeholders. In addition, the social/educational interests that are broken down into generic and individual interests, are related to their relevant different physical school building environmental scales. Finally, this strive for internal system balance between societal educational interests and the AEC design process stakeholders' interests is studied. This system analysis generates a theoretical framework that also requires validation from practitioners during the process of establishing the theoretical framework and instruments.

Validation is not carried out according to regularly used methods, but is exploratory and preliminary with respect to the theoretical framework and the instruments and guidelines developed for school building design. The most opportune way for this is to periodically test the development of the theoretical framework in experts' meetings, attended by a wide range of social and technical participants. It is therefore not a formal validation, but one focused on finding support for and understanding of the extent to which the problems are recognized, the elaborate problem and system analyses and the instruments developed to arrive at a synthesis of integrated solutions. The validation process of the theoretical framework, the elaborate instruments and guidelines, will be described in chapter 5, which includes the AEC industry design process and a synthesis of social/educational and sustainable development relationships. To show how the sub-studies are related cumulatively and how the validation process was incorporated during the study, a reading guide is included.

1.10. Reading guide

The research aims are formulated and answered by cumulation of the chapters 2 - 5. The main question will be addressed fully in chapter 6. With a focus on improving the balance between all three dimensions and scales of interests, the identification of underlying self-similarity pattern relationships between human behaviour, sustainable development and design and processes have been studied to establish a robust theoretical framework.

Chapter 2: The aim of this research was to analyse the physical problems at multiple levels, to recognize the problem causes and effects and their relationship with stakeholders' behaviour and the physical learning environment shells. An integrated model positions three studies of three kinds of interest and mutual relationships with social interests, environmental interests and AEC industry stakeholders' interests to analyse the persistent problems in an integrated way. A systems thinking approach was used to develop a theoretical framework to generate a general basis for the guidelines for practical application.

Chapter 3: The aim of this research is to achieve an architectural synthesis from the theoretical approach, focused in particular on primary school building end-users, because of the recognized level of scaled imbalances within this dimension on the one hand and the still unknown requirements of end-users on the other. A method based on interests determines end-users' generic and individual interests, in addition to societal interests. The relationship with the required end-user design quality indicators will be studied from a biological, physiological and psychological point of view. From a social interest perspective, a theoretical model balances the interests of society, generic end-users and individual end-users in relation to the different physical learning environment shells. The analysis leading to the establishment of the interest characteristics of end-users will lead to the needs-centred guidelines for Dutch primary school building design.

Chapter 4: The aim of this research is to further develop the theoretical framework to find justification for a consistent pattern from underlying pattern similarities and interrelationship perspectives between social interests and environmental issues to reduce school building design complexity. To unravel the complexity of interwoven primary school building design from a sustainable development perspective, this approach balances the social, environmental and school building design indicators (e.g. building structure and flexibility). The outcomes of end-users' interest characteristics were related to the sustainable development factors. Subsequently, a relationship was studied by connecting the design factors, as a morphological approach of the programme of requirements, to these aforementioned factors. An analysis led to the sustainability-centred guidelines for Dutch primary school building design.

Chapter 5: The aim of the research is to future-proof Dutch primary school design whilst dealing with its complexity. Analysis of the problems and challenges showed that the challenge is that the capacity of school building design processes to deal with complexity will be improved when a way is found to include and balance all interests, made up of three clusters: (1) psychological, social and educational, (2) environmental and (3) the interests of the parties from the AEC industry and its institutions. Several design and process methods that are regularly used in building construction were related to the developed behavioural patterns and to sustainable development, and morphological design to biophilic design and Belbin types of roles. Additionally, the framework needs to anticipate future changes by considering the values of the different factors and their system robustness. The validation process describes the results of different experiments to verify and gain support from stakeholders involved in school building design during a process lasting several years. A multidisciplinary team was established comprising stakeholders from AEC industry businesses, municipalities, education, research and local communities and was asked to collaborate to establish a new school building based on the research outcomes presented.

Chapter 6: The outcomes of the theoretical framework led to an integrated robust model involving the economic, political and technical interests and the new drivers for change of environmental, social and design process stakeholder interest dimensions to generate a multi-level balance between the different interest characteristic scales and school building design and process scales. This final chapter will present the results and recommendations. The main question is answered by considering the integrated approaches of multi-level social interests, sustainable development and school building design interests. It considers current major global dynamic adaptive system changes, which influence school building system stability. An appendix with an overview of guidelines will complete the research. An overview of the cumulatively related chapters shows the system analysis-based approach for the established theoretical framework (see Figure 1.2.). A reading guide shows in more detail the instruments and guidelines established (see Table 1.1.).

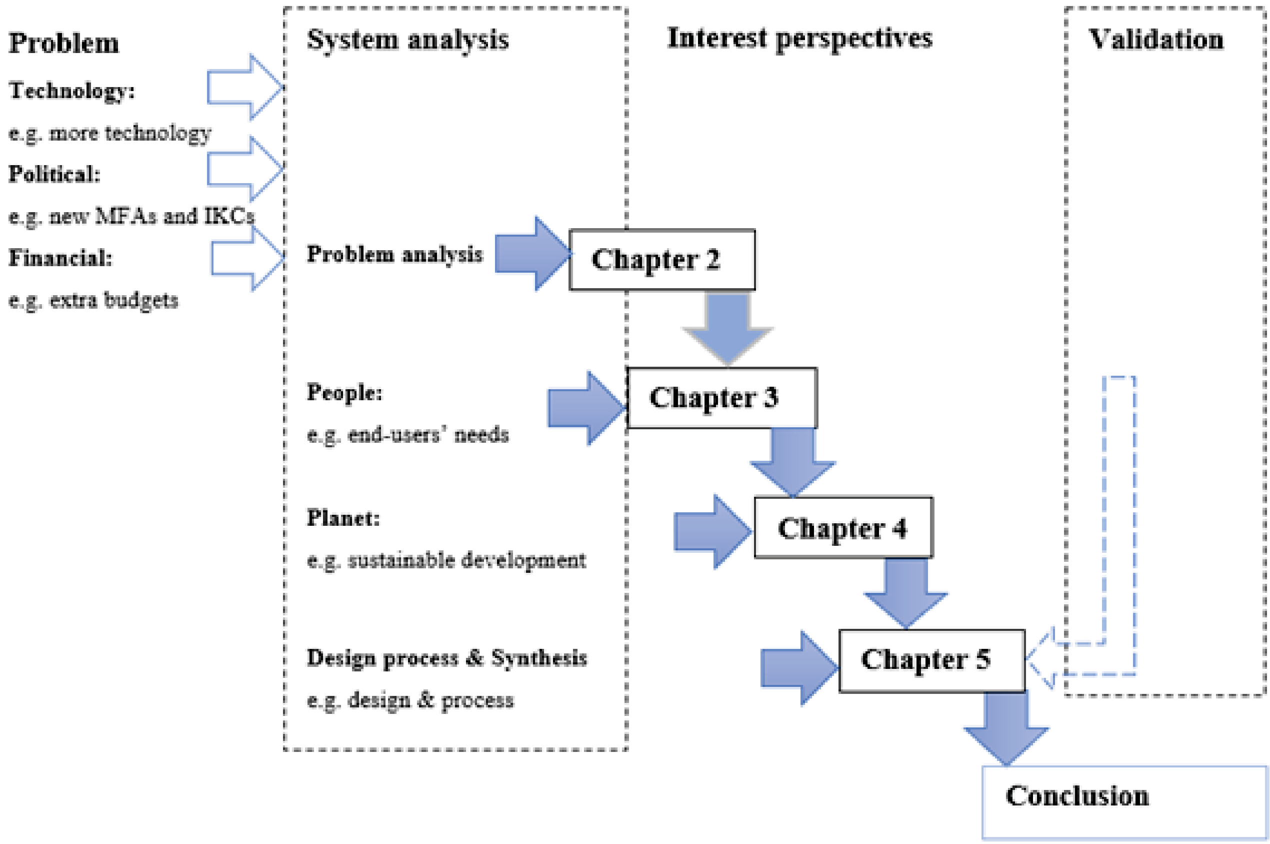

Figure 1.2. Overview of the chapters of the interrelated multi-level study.

Table 1.1. Reading guide.

Section	Research	Chapter	Method
Problem analysis		2	Theoretical research: Model development: dimensions of interests, balances, level of scales as drivers for change; Instruments: cause-effect analysis; basic structure for the establishment of guidelines.
Interests			Theoretical research:
	Social/ educational interests	3	Balance interests of individual end-users, generic end-users and society with school building; Instruments: integrative method to weight the end-user's interests in the continuum scale of social interests; a system to elaborate the design quality indicators for end-users; needs-centred guidelines.
	Environmental interests	4	Balance societal and environmental interests with school building design Instruments: integrative method to weigh the sustainable interest in design scales; sustainability-centred guidelines.
	AEC industry interests	5	Synthesis of social, environmental and design process stakeholder-related interests; Instruments: integrative method to balance the interests in process scales; process-centred guidelines; Validation process: practical research: adoption of steps and practitioner experiences.

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Chapter 2
PROBLEM ANALYSIS

Crisis in Dutch primary school-building design solved by paradigm shift?

ABSTRACT

There is an ongoing social debate concerning Dutch primary school design related to persistent physical environmental problems such as poor indoor quality and inflexible spatial elements. Increasing complexity and building construction process failures, as well as inexperienced school principals, also seem to be important impact factors. This analysis employed a multilevel model which reflects the interrelationship between needs, interests and views, which are in turn responsible for physiological, psychological and biophysical problems in the school-building design process. It shows that antagonistic interests seem to impede rational innovative pathways which could be used to enhance synergetic solutions. These interests impact on the process by affecting the objective decision-making process adversely, making the problems faced unnecessarily complex due to competing subjective desires. The new approach proposed here increases awareness by mirroring actors' behaviour and their most important needs, possibly leading to a decrease in school-building design problems. By means of introducing a positive psychological approach and viewing these profound human needs as a social fractal, it is possible to create a new paradigm which might solve the school-design crisis. As a lever for changing the current processes, new tangible school-building design parameters also might become available. The aim of this study was to analyse the current problem patterns and assess the possibility of producing more synergetic solution patterns. On this basis, we developed a needs-centred guideline for primary schools.

Keywords: human needs; personal learning environment; primary schools; school-building design; social fractal

Additional information chapter 2	
Authors	R.de Vrieze[a], H.C Moll[b]
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Place of publication	R. de Vrieze & H.C. Moll (2015): Crisis in Dutch primary school-building design solved by paradigm shift?, Intelligent Buildings International, 7:1, 36-60, DOI: 10.1080/17508975.2014.943152 Original text has been slightly changed to improve the consistence of the thesis by using some other words and styles.

[a] Hanze University of Applied Sciences – Research Centre for Built Environment NoorderRuimte, Van Doornveste, Zernikelaan 11, 9747 AS Groningen, The Netherlands.
[b] University of Groningen - ESRIG Energy and Sustainability Research Institute Groningen, Centre for Energy and Environmental Sciences, Energy Academy Building, Nijenborgh 6, 9747 AG Groningen, The Netherlands.

2.1. Introduction

The effect of the physical school environment on teaching and learning has been studied for many years in order to predict and determine the positive or negative impact of these parameters on pupils' learning. Nonetheless, current school-building designs still result in poor indoor air quality, interior climatic impediments, inadequate lighting, noise nuisance, bad acoustics and functional pedagogical impairments. For years, poor indoor environmental quality (IEQ) has impeded improvements to pupils' performance and harmed pupils' well-being, behaviour and health. The increasing complexity of school-building design, the involvement of inexperienced principals in it, the new 'learning architecture' construction materials and detailing failures undertaken as experiments in practice, as well as a failing traditional building construction sector, are just some factors which suggest that an overall crisis is also affecting Dutch school-building design. Recent research shows, however, that some school-building design improvements have occurred since 2006, but in the meantime some billions of euros are now required to address the Dutch situation (Oberon 2013). The failures in the sector have been investigated by several architectural design institutions, such as the Dutch knowledge centre for architectural policy (Architectuur Lokaal 2008), the Foundation for Architectural Stimulation (Rodermond et al. 2009) and the Foundation of Dutch Architects (BNA 2011). It seems that it is a complex issue and there is an overdue need to address the current situation of a mismatch between physical and pedagogical goals. According to the former government architect advisor, Van der Pol remarked in 2010, 'the search for more synergetic solutions will always result in inevitable compromises'. The extent to which this is the case is a major aspect in this study and will be analysed in detail. Although the Dutch crisis has its own historical origins, generally speaking the overall impediments to better design are identifiable in other Western countries. For example, in the learning conclusions presented during the International Study of 'Innovative Learning Environments' at the Centre for Educational Research and Innovation in 2011, Istance (2011) stated that while the amount of 'research based on learning grows so far there is a "great disconnect" between policy and practice', which was also clearly noted by the OECD (Dumont et al. 2010). Two of the seven learning conclusions stand out: 'environments should be highly attuned to learners' motivations and the importance of emotions and be acutely sensitive to individual differences, including in prior knowledge' (Istance 2011). The need for technological and other forms of growth by means of improvements in pupil's performance is emphasized in the Ingenium project by Heppell (21stCentury 2013), in which the learning space is built to be adaptable to the needs of different types of learners: 'kinaesthetic learners for example, who might not benefit from traditional classrooms, had ample space that allowed movement' (21st Century 2013). 'The 21st century is challenging old notions of learning spaces' (21st century2013).'Technology and collaborative work environments are changing the design of learning spaces'(21stCentury2013). Experts such as Heppell 'hope that the emerging paradigm will translate into improved learning spaces and influence future architectural design' (21st Century 2013). In addition, it is remarkable how rigid school-building design actually is, in contrast with the subjective, psychologically based decisions of the actors involved in the design process. As Ariely writes in Predictably Irrational (2008), 'understanding irrationality is important for our everyday actions and decisions, and for understanding how we design our environment'. This means that a variety of often antagonistic interests should be considered, which will include both rational and irrational elements. To explore the extent of the current crisis in Dutch school-building design (and seemingly that of Western countries in general), a systematic multi-level approach will be applied here to unravel the complex of needs, processes and learning-environment relationships (Analyses). Using a psychologically based approach to human needs, we generate a hypothesis within a behavioural perspective that could change current views and patterns of school-building design (New paradigm: generating a needs-centred framework). A multi-level modelling approach and the integration of human needs (supported by two examples) will deliver a needs-centred framework offering a new guideline for primary school design (New model: application of the needs-centred framework for a new guideline). This opens a new debate concerning the extent to which fundamental psychological needs and technological features can be related to biological and physiological needs within a biophysical learning or other environment. The main aim of this study was not to provide a comprehensive answer to the question posed in the title of this article but to deliver a hypothetical framework which might be used in practice on the basis of a greater insight into current primary school-building design problems. It is hoped that this method might untangle the issues and achieve more integrated, sustainable, healthy primary school-building design as the basis for a new paradigm which could solve the present crisis.

2.2. Analysis

The systematic analysis is framed on the one hand by a multi-level system approach encompassing needs, processes and material/technological dimensions, and on the other hand by the psychological, physiological and biophysical environment problem-effect domains. The biophysical environment has its own dynamics in relation to needs and processes within any specific place and time. The analysis is primarily based on identifying the impacts of the problems raised. The dimensions are framed by an externally oriented (hierarchically based) three-axis model of the relationship between the micro-, meso- and macro-levels (see Figure 2.1.).

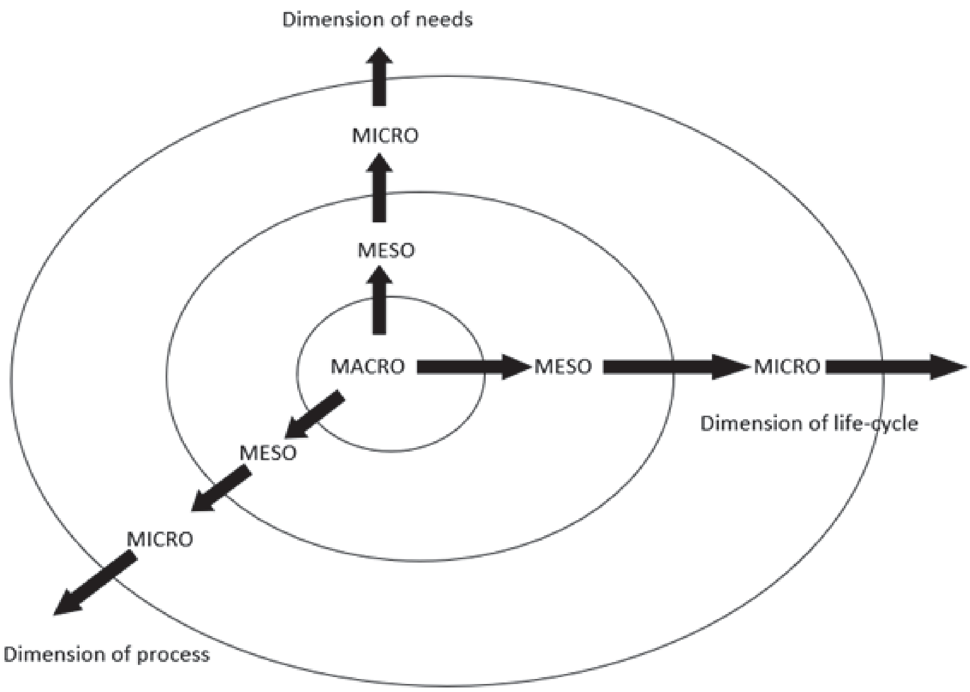

Figure 2.1. Structure of dimensions.

The multi-level analysis includes:

1. Micro-system:
    - Needs: school-building users;
    - Processes: new ‘disruptive’ technological disciplines;
    - Life-cycle: building and surrounding characteristics, end phase of materials and place related energy systems.

2. Meso-system:
    - Needs: interests of educational institutes (management boards, local municipal and educational authorities, and education sector advisors);
    - Processes: school principals, stakeholders and the building construction sector, and local authorities;
    - Life-cycle: building and surrounding characteristics, maintenance, operation, refurbishment, re-use time phases and place (physical shells) relationships.

3. Macro-system:
    - Needs: socio-cultural views and government policy;
    - Processes: government school-building construction legislation, budget and architectural design typology;
    - Life-cycle: building and surrounding characteristics, initiative, design and construct phase of materials, and place-related energy systems.

A rather similar dimension partition based on a twofold multi-level approach to the transition from current design processes to a more integrated design approach was introduced by Zaal (2005, 2007). Support for our multi-level approach is also found in the field of environmental psychology (Steg et al. 2012):

- Social design (associated with our axis of needs): the best service of human needs and wants, enhancing users’ involvement;
- Biophilic design (associated with our axis of life-cycle): the integration of natural shapes and forms in architecture, natural evolutionary approach;
- Evidence-based design (associated with our axis of processes): the best available evidence of effective design, using the best knowledge (Steg et al. 2012).

Social sustainability (the needs axis), biophysical sustainability (the life-cycle axis) and economic sustainability (the process axis) are also identifiable. The effects of current physical impediments are structured by:

- Psychological domain effects: actors' behaviour and performance impediments related to the multi-level axes of needs and processes (for example, the actors' psychological state of mind [mood], character, gender, age, culture, attitudes, beliefs, identity, learning styles, sensory experience associations, etc.);
- Physiological domain effects: the physiologically perceived health and comfort impediments which concern the physical state of end-users (for example, sensory experiences and health performance);
- Biophysical and environmental ecology domain effects: the surrounding biotic and abiotic effects on all actors or environmental agency impediments which concern the technological building characteristics (for example, physical exposure and sensory experience of material and technological systems).

Based on various literature in architectural design research (see Introduction), physical impediment problems can be related to the three domains within the threefold dimensions:

1.1. Relationship between the domains of psychology and physiology:

Needs:

- Micro: poor indoor environment affects pupils' health (see Example 1);
- Meso: inexperience of principals affects school-building usability;
- Macro: national government ongoing policy changes affect efficient investment.

1.2. Relationship between the domains of psychology and bio-physiology:

Processes:

- Micro: new technological knowledge and disciplines affect traditional processes;
- Meso: traditional processes affect new integrated innovations;
- Macro: striving for minimal legislation boundaries affects minimal building-performance quality standards.

1.3. Relationship between the domains of bio-physiology and physiology:

Life-cycle:

- Micro: artificial (toxic) materials affect the personal learning environment (PLE);
- Meso: building modifications and changes affect the local community environment (see Example 2);
- Macro: new school-buildings affect the social living environment.

In relation to these three environmental domains, evidence-based mutual relationships are identifiable which can subsequently be related to the learning environment. For example:

- Psychological and physiological: reduced temperature (from 23.6°C to 20°C) tends to reduce the number of errors committed in acoustic proofreading by 10% (Wargocki et al. 2005); low ventilation rates in classrooms significantly reduces pupils' attention and vigilance, and negatively affects their memory and concentration (Bakó-Birób et al. 2012); individual desired room temperature levels differ by gender and age (Schellen et al. 2010);
- Physiological and biophysical: massive wooden internal walls in classrooms decrease pupils' heart rate substantially (Mayrhoffer 2010).

In addition to these mutual relationships, ancillary school-building benefits are also identifiable as accruing individual, organizational and social benefits. For example:

- Low green-building performance outcomes which are not directly related to energy efficiently and green features, benefits users (Heerwagen 1998).

According to Heerwagen (1998), a facility's success must be considered in terms of three interrelated domains: environmental sustainability, organizational effectiveness and human well-being. In addition to these mutual relationships, cyclical relationships can also be identified; for example, in relation to the learning environment:

- Psychological quality aspects might influence sustainability quality (e.g. the need to open a window for fresh air might conflict with a heat recovery system);
- Physiological quality aspects might influence the psychological learning environment quality (e.g. concentration problems in the classroom caused by frequently coughing);
- Biophysical quality aspects might influence the physiological learning environment quality (e.g. indoor air quality problems caused by fine dust from outside).

Considering the problems mutually and cyclically, these relationships are also recognized by Mobach (2009) in his organizational–spatial constellation of discipline-interwoven, cyclical movements contingency model (Figure 2.2.).

Within this complex attempt to achieve a greater harmony similar to environmental problems, we have identified a fundamental starting point for the causal relationship between school-building design problems and human behaviour by Scott and Koger (2005): 'these problems are not really problems of the environment, but are the result of a mismatch between the ways in which human beings fulfil their needs and wants and the natural processes that maintain environmental integrity'. It has been revealed in the USA that no psychology is included within more than half of the environmental study programmes and nearly 90% of the environmental science programmes (Scott and Koger 2005).

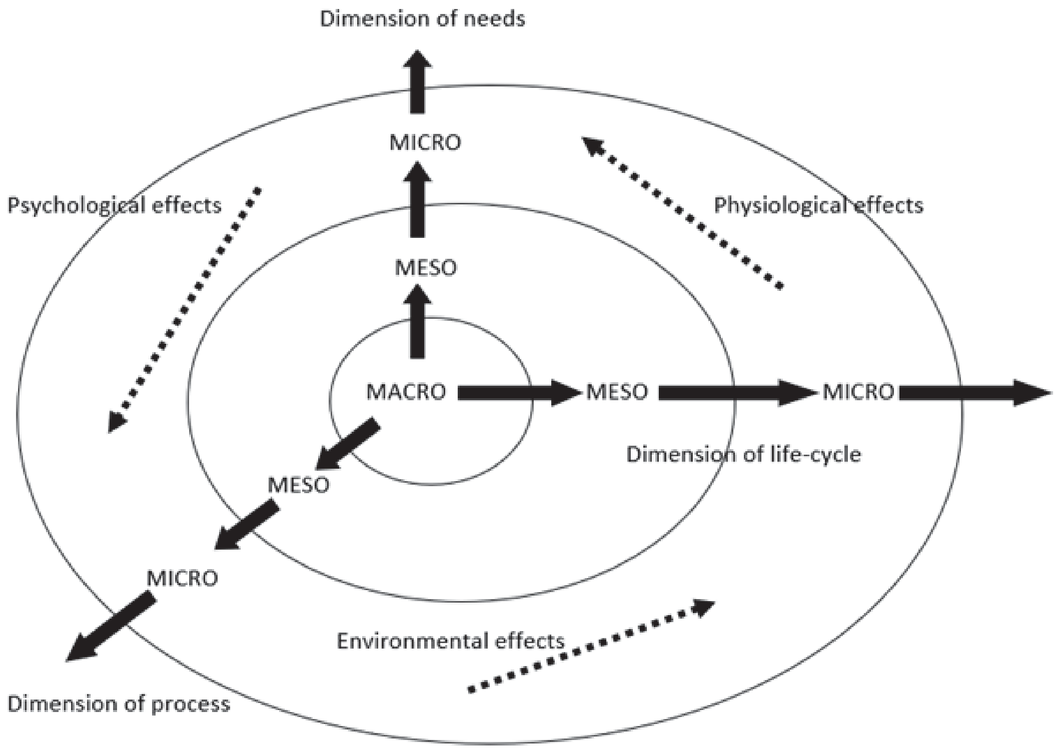

Figure 2.2. Structure of dimensions and cyclically related domains.

In order to extend the domain beyond a purely rational-objective approach, we now introduce the ‘irrational’ element, which examines subjective psychological impacts.

2.2.1. *New paradigm:* generating a needs-centred framework

All environment problems (and learning environments) seem to be due to the ‘inadequate or improper effects of human needs fulfilment: as an “unresolved” working mechanism’ (Maslow 1954), ‘since every person constantly seeks satisfaction of their own basic human needs’. The (learning) environment is thus affected by basic human needs and control behaviour (Dorst 2005). Generally speaking, human behaviour is a combination of controllable conscious elements and automatic unconscious components related to a variety of human needs. Although a variety of human needs and approaches to these makes it difficult to generalize, in terms of the applied sciences, human-needs theories share considerable similarities. For example, Pittman and Zeigler (2007) identified the need for social connection as one of five profound human needs: ‘the most obvious of [these] is that five of the six theories share, at the level of the social group, an assumed need for relatedness, belonging, or affiliation’ (Pitmann and Zeigler 2007). With respect to these relationships between behavioural patterns and human needs, we have identified positive psychology as being useful in any practical application. As stated by Seligman and Csikszentmihalyi (2000): ‘positive psychology is primarily concerned with using psychological theory, research and intervention techniques to understand the positive, adaptive, creative and emotionally fulfilling aspects of human behaviour’ (see also Seligman’s book, Learned Optimism). The definition of positive psychology varies, with Proulx (2013) stating that it involves: ‘exploring the keys to a happy and meaningful life’, while Seligman and Csikszentmihalyi (2000) claim that it is, ‘a science of positive subjective experience, of positive individual traits, and of positive institution’s promises to improve the quality of life and also to prevent the various pathologies that arise when life is barren and meaningless'. The theory aims to provide the opportunity for a lifestyle transition through reprogramming internal associative and cognitive patterns (e.g. thoughts, beliefs, etc.), as well as addressing biological conditions (e.g. sensory experiences).

One of the notable insights from the World Congress on Positive Psychology (2013) was that the physical environment influences our mental state of mind and interactions with others. When surroundings are in accord with individual's psychological and biological needs, they will experience greater well-being (Proulx 2013): 'we shape our dwellings, and afterwards our dwellings shape us' (Proulx 2013).

Within the field of positive psychology, a coaching method known as neuro-linguistic programming (NLP) inspired us to look further in the direction of an emotion-centred approach. Through neuro-associative Conditioning (NAC), developed by life coach Anthony (Tony) Robbins (21st Century 2011), it has been found that 'we are all driven to fulfil the basic human needs. The six basic needs are not just desires, but profound needs which serve as the basis of every choice we make'.

Robbins takes an emotion-centred approach and uses a coaching technique to transform unwanted cognitions and unpleasant thoughts, and this in turn changes behavioural patterns, effective in clients who fully support the process. The technique uses an emotional lever to change current patterns of behaviour into new ones through a process of transition. Using seven transition stages, the NAC method appears to be straightforward, which inspired us to investigate further. With respect to our main aim and focus on developing a method for practical use, we adopted a number of insights to support our approach. For example, according to the behavioural insights team (Sanders et al. 2012), a lever for change increases when it is easy to use, it meets the needs of end-users, it is focused on social norms and it is the right time for a transition. On this basis, we created a simplified method, encompassing a humane attitude towards children, a social norm of growth and the right time to introduce change (the crisis).

The Dutch and Austrian Health Balance Group (www.healthbalance.nu) method, based on Robbins' NAC, uses a Triad model to diagnose emotional threshold patterns, defined by

- physiological elements (sensory experiences and physical attitude);
- psychological elements (thoughts, beliefs and focuses).

Adapting the NAC approach, here we use the first stages: the diagnosis, the lever for change and, in addition, the destruction of the old pattern (which will occur during the crisis), and exploration of a new pattern built by identifying new fundamental school-building parameters (see below). The seven stages of the NAC are (with the addition of our examples) as follows:

1. Diagnose the situation (e.g. IEQ problem);
2. Create a lever for change (e.g. focus on actors' personal feelings of responsibility and their effects)
3. Destroy the old pattern (e.g. school-building construction process crisis);
4. Create a strong alternative (e.g. focus on the PLE);
5. Make sure it is permanent (e.g. focus on proven results);

6. Test whether the change is real (e.g. focus on actors' new positions and attitudes in process);
7. Create a strongly supported learning environment (e.g. focus on future performance).

The NAC method uses six core elements related to human needs (21st Century 2011), which include a number of paradoxical needs. Both the needs and these paradoxes should be well understood because they influence behavioural responses:

Paradox of fundamental needs, Pair 1:

- certainty (the need for security/safety/comfort/consistency);
- variety (the need for challenges/excitement/diversity).

Paradox of higher positioned needs, Pair 2:

- connection (the need to be loved, appreciated by other human beings in a group/ identity);
- significance (the need to feel important/needed/wanted/worthy/special).

Highest needs:

- growth (the need for constant development emotionally/intellectually/spiritually);
- contribution (giving beyond ourselves).

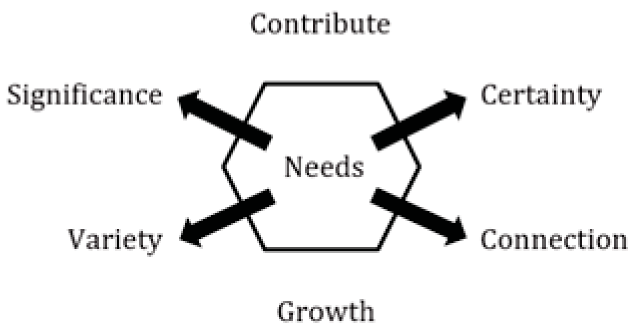

Figure 2.3. The social fractal of human needs and paradoxes.

In addition to offering a method for changing behavioural patterns, the method also inspired us in its understanding of core human needs within both the physical and social environments. We thus researched the mutual and cyclical domain relationships and evidence-based theories of the foundation of human needs with respect to

- psychological relationships;
- psychological and biophysical environment relationships;
- psychological and physiological relationships;
- time and place relationships concerning the psychological, biophysical and physiological influences.

2.2.1.1. Psychological relationships

One of the main motivation theories is self-determination theory (SDT) (Deci and Ryan 2009), within which three intrinsic motivation drivers are described: feelings of competence, autonomy and social relatedness. Needs fulfilment should necessarily care for psychological growth, integrity and well-being (Deci and Ryan 2009). According to Deci and Ryan (2009), '*although underlying different goal contents might have different relations to the quality of behaviour and mental health, and different degrees of needs satisfaction, a relationship between the social context and individual differences that support satisfaction of the basic needs and facilitate natural growth processes are associated with motivation, performance and well-being*'.

We also identified similarities between the NAC method and SDT which strengthened the relationship between motivation and human-needs relationships. The motivation factor for feeling 'connected' is obviously one such similarity. Using a reductive approach, we assume that the 'feeling of competence' might also be associated with a combination of feeling 'certainty' and 'growth' and that the 'feeling of autonomy' can be associated with a combination of feelings of self-realization, such as the need for significance and growth. By 'feelings' we mean an emotionally profound relationship, recognized in SDT and in the NAC approach.

The influence of the perception of the physical learning environment on pupils' cognitive performance (and motivation); for example, class size, class equipment, methods, peers and family, is marginal according to Hattie, who quantifies the influence at only 5–10% (Hattie 2003). Hattie also found that 50% of learning performance is determined by pupils' individual characteristics (Hattie 2003). The learning environment has identifiable effects on pupils and teachers (Higgens et al. 2005). It seems to be 'very complex to come to firm conclusions about the impact of physical learning environments and evidence-based statements, because of the multi-factorial nature of learning environments and the diversity of approaches in the research literature' (Woolner et al. 2007). Barrett et al. (2013) identified six school design parameters (colour, light, complexity, connection, flexibility and choice) as important, with the learning progression contribution related to these parameters being, on average, 25%.

The relationship between external learning-environment impacts (e.g. sensory experiences such as light, warmth and noise) and internal impacts (e.g. human needs, emotions and behaviour) are influenced by motivational factors: 'everyone can be motivated by their drivers to fulfil' (21st Century 2011). We assume there are no particular distinctions within these physiological and psychological aspects and that both work together. To be primarily motivated by these drivers seems to suggest that the social aspects might have more impact on learning than the physical parameters.

Philosopher and author Nussbaum (2006) has argued that autonomous feelings should be considered stronger than feelings of competence, social relatedness and certainty. According to Nussbaum, emotions are important factors in processes that fulfil human needs. Nussbaum also argues that the influence of autonomy is the strongest intrinsic motivational factor. We linked these relationships and similarities to the six core human needs outlined in the NAC method, related to motivational aspects and emotional relationships especially.

The 'NMC Horizon Report: K-12 Edition' (2012) introduced the term 'PLEs' (Johnson et al. 2012). The notion supports self-directed and group-based learning designed around each user's goals, with a great capacity for flexibility and customization (Johnson et al. 2012). In the context of describing how learning accommodates adjustments related to virtual and autonomous fields, it is suggested that the heteronomous approach of one-size-fits-all will be displaced by the introduction of new technological innovations (e.g. quantified-self) (Wetering et al. 2013). In addition to this experience of learning-environment sensitivity, human needs and motivational aspects are explicitly related to autonomous aspects, as described by Steemers and Machanda (2010): ‘when a shortage of autonomous feelings is experienced, it results in decreased satisfaction’.

Additional support for the importance of autonomy was found by Hofkins and Northen (2009), who describe the feeling of ‘agency’ as being essential for emotional well-being.

For educators, autonomy related to physical control (e.g. heating, ventilation and organizing the classroom) is crucial for pedagogical success, in addition to social control (Hatcher 2005). With respect to the view of evolutionary psychology on human needs, a fundamental sense of grounding is identified by the phrase ‘the tragedy of the commons’ This term refers to the evolutionary framework of human behaviour identified by Vugt (2013):

- relationships (we assume an association with the need for connection);
- having status (we assume an association with the need for significance);
- earning short-term profits (we assume an association with the need for certainty);
- actors’ autonomous influences are sensory driven (we assume an association with the need for certainty);
- actors’ awareness of copying behaviour (social group needs vs. individual needs, we assume an association with the need for certainty, variety, etc.).

The evolutionary impacts intervene in the process-stage decisions as unwanted thresholds. Associating these ‘big five’ (Vugt 2013) factors with human needs, enables a higher evidence base and provides the opportunity to manage school-building design complexity and the uncertainties more subtlety, based on only six core human needs.

2.2.1.2. Psychological and biophysical relationships

In the search for causal relationships between physical learning-environment problems and behavioural impacts, we identified sensory experience as one of the physical parameters (Robbins, ‘emotion-centred Triad’) necessary to fulfil underlying human needs. A simplified relationship between psychological needs and learning environment (the biophysical environment, time- and place-related) is found in ‘feelings of social connection’, illustrated, for example, by ‘a welcoming entrance and common areas that foster a sense of community’ (21st Century 2013).

Similarities to the six core human needs are also identifiable in aesthetic amenity methods such as the image of the city (Lynch 1960), the information processing model (Kaplan and Kaplan 1987, 1989) and the Handbook of Environmental Psychology (Bechtel and Churchman 2002), in concepts such as ‘coherence’, ‘complexity’, ‘legibility’ and ‘mystery’ (Kaplan 1987; Kaplan and Kaplan 1989) which we argue correspond to the need for certainty, variety, relatedness and growth, respectively.

Within the threefold environmental psychology approach mentioned above (Steg et al. 2012), we identified similarities between three multi-level models and the six core human needs, which can be concisely described as follows:

- the dimension of needs according to social design (associated with the need for connection);
- the dimension of life-cycle levels according to biophilic design (associated with the need for certainty);
- the dimension of processes according to evidence-based design (associated with the need for contribution).

In addition to this identification of environmentally based psychological needs, we also recognized in this approach a notable emphasis on 'social-group related' needs (need for certainty, connection and contribution).

2.2.1.3. Psychological and physiological relationships

Psychological and physiological parameters are crucial in the fulfilment of personal needs (Bluyssen 2009). In the search for the essential learning-environment parameters, fundamental human needs might illustrate a relationship with pupils' sensory responses. In this field, we argue that social and physiological fulfilments both contribute equally to the fulfilment of emotional needs. This is underpinned by the equality of biological responses (see Bluyssen 2014). As Barrett et al. (2013) suggest, both psychological and physiological needs are essential parameters for determining the learning environment. In addition to the physiological parameters of colour and light, the more social and self-realization-based parameters of connection, choice, flexibility and complexity also seem to have an influence on core human needs. Barrett et al. (2013) state that 'a wide range of factors involved, however, still remain a significant challenge'. Thus, it might not be the parameters, but the need behind them and how the individual pupil responds to this need. Cao et al. (2012) stated that the discomfort of people reflects the fact that the integration of physiological and psychological elements is influenced by many factors. Bluyssen's book The Indoor Environment Handbook (2009) allows us to identify the relationship between user's needs and indoor environments to examine how psychological needs are interrelated with physiological (biological) needs: safety, belonging, esteem, cognitive, aesthetic, self-actualization and transcendence. Both psychological and physiological parameters, considered in terms of their interactions, are crucial in the fulfilment of personal needs (Bluyssen2009).This also supports the assumption of the value of using human needs more widely (socially and physically) in relation to school-building design parameters, rather than considering only physical or social factors. In their book, Learning Spaces' Human-Centred Design Guidelines, Gee and Miller consider universal human needs and learning principles to be the first priority (cited in Oblinger2006, 10). In our approach, we argue that human needs might be identified as a foundation for establishing the physical parameters of the learning environment.

Within the social fractal of human needs (see Figure 2.3.), we can identify paradox-based relationships, mutual relationships (sideward) and hierarchical relationships (upwards). Within these three parameters combined, we identified a spiralling dynamic mechanism with outward directed needs (group, social orientation) and inward-directed needs (self-realization orientated). This twofold approach pattern is significantly related to antagonistic interests, for example, because of the orientation of a group's in fluences and identity patterns.

These movements between integration and differentiation, attention to oneself and subsequently to the social community, are also recognized by Csikszentmihalyi in The Evolving Self (1993). Our social fractal gives us an insight into how needs fulfilment might intervene in relation to the interests of all antagonistic actors and the decisions made, with individual and group-reflecting behaviour operating as a complex adaptive system constantly searching for harmony (Figure 2.4.).

In addition to this, new studies suggest that we not only think with our brains, but also with our bodies (Bennet 2008). Thus, we attempted to identify how psychological associations, physiological sense experiences and deeper biological (body) issues demand integrated interaction, which is emotionally fulfilled if the needs are responded to, or strives for fulfilment if integration is not achieved. A basic claim of the embodiment framework is that all psychological processes are influenced by body morphology, sensory systems, motor systems and emotions. As such, the framework holds the promise of providing a unifying perspective for psychological research (Glenberg 2010). A key to the Montessori pedagogical method is the idea that pupils learn best in a dynamic environment full of motion and involving the manipulation of physical objects (Glenberg 2010). We suggest that this meets the human needs (paradox) mechanism model.

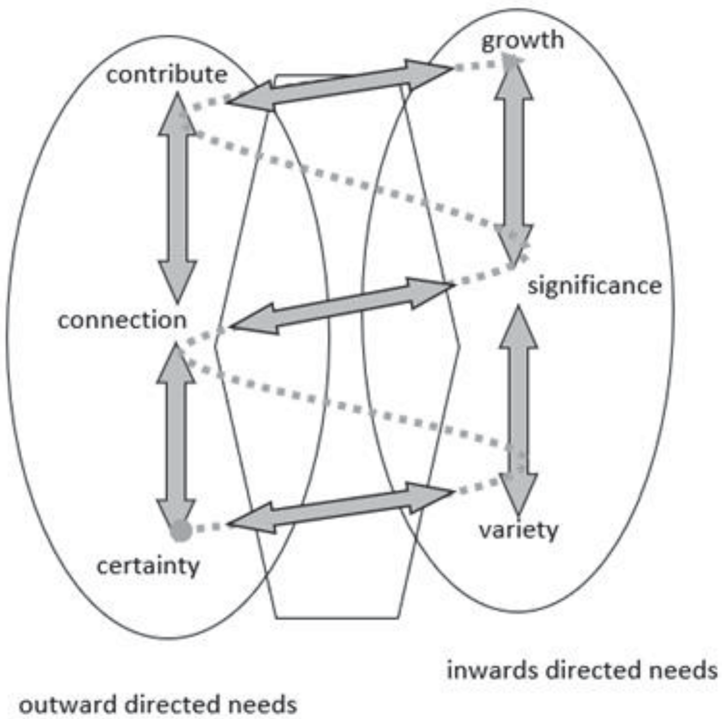

Figure 2.4. Social fractal of spiral and paradox related outward-directed and inward-directed human needs.

Figure 2.5. indicates the positioning of the social fractal of six core human needs into the multilevel model, on the needs and processes axes (Figure 2.5.). By means of the integration of this social fractal of human needs into the multi-level model of problem-effect domains and multi-level actor dimensions, the opportunity to diagnose a specific school-building design problem in relation to subjective aspects is possible.

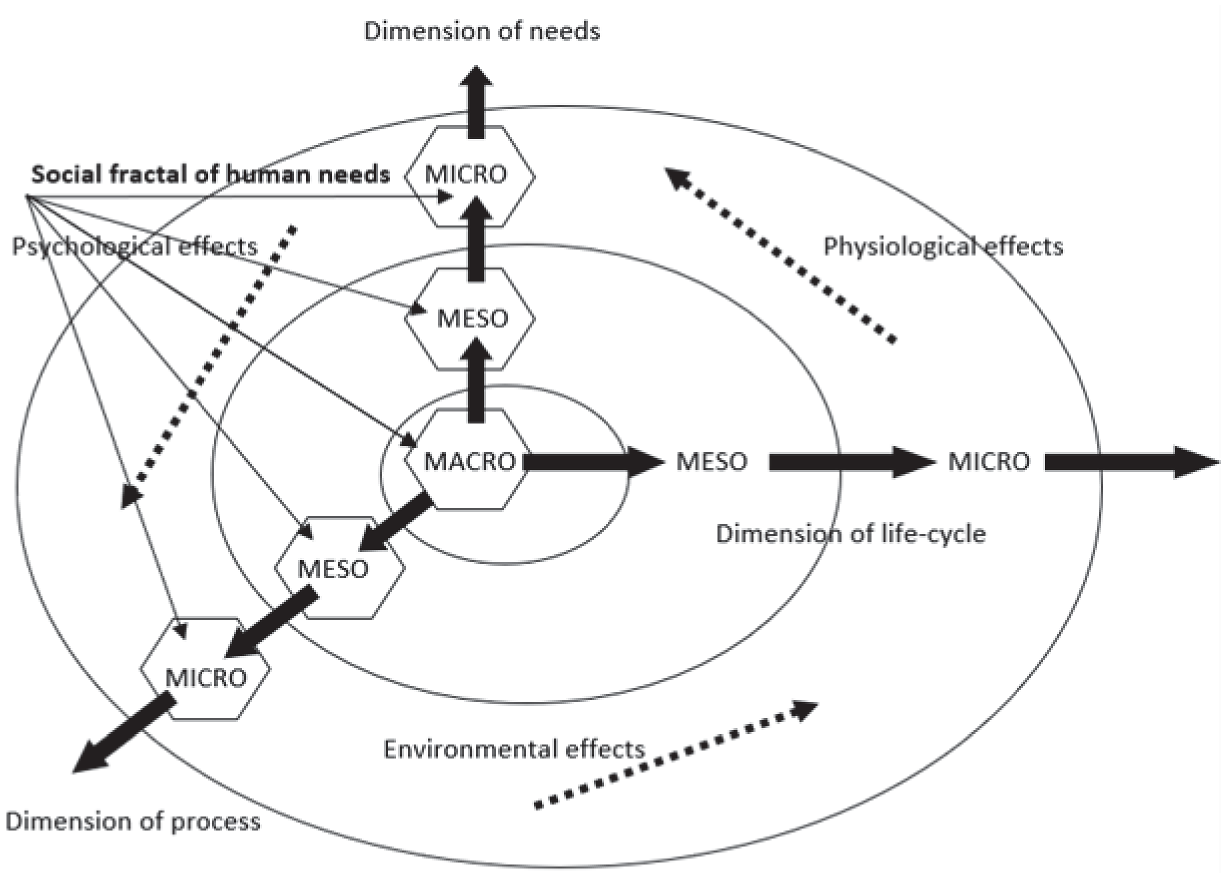

Figure 2.5. Fractal positions into multi-level dimensions and domain relatedness.

<u>2.2.1.4. Time and place-related influences</u>

Time relationship In order to consider the physical problems in a time-related perspective, the six core human needs can also be identified in terms of child development psychology. During a school-design expert meeting in 2010, a group of 20 learners (age 8–25 years) was discussed in terms of their human needs preferences. These were identified as follows:

- youngest pupils prefer a need for certainty (e.g. a safe environment);
- older pupils prefer a need for variety (e.g. spatial challenges);
- secondary students need for social relatedness and significance (e.g. separate, comfortable places and need for identity with different groups);
- university students need for growth (e.g. sufficient project rooms);
- teachers need for contribution (e.g. help pupils in their learning process in relationship to private situations).

Pupil and student needs were also identified in an expert meeting report published by Onix (2012). The micro needs of the youngest children – certainty and variety – were also recognized by Walden's *Schools for the Future* (2009): 'School is about independent growth as well as proactive support, and it is characterized by both continuity [certainty] and adventure [variety]'.

In relation to long-term human needs in the learning environment, relationships between school-building typology and macro-level time-related interests are identifiable within a historical perspective. With respect to early twentieth-century school-design accents, for example, certain needs can also be identified (Bakker 2013):

- certainty (e.g. early twentieth-century playground fences and clear school design);
- variety (e.g. increasing school profile diversities and religious or otherwise);
- social connection (e.g. after the Second World War, there was a period of social urban planning relationship within schools);
- significance (e.g. appreciation and acknowledgement of school performance);
- growth (e.g. decentralization of responsibility and performance-based goals).

This long-term perspective that emphasizes transformation on the basis of human needs, also increasingly offers space for aesthetic and other non-quantifiable properties (Bakker 2013). We assume that these non-quantifiable parameters such as aesthetics are examples of how the need for significance (sensory experiences adjusted to personal or group needs) can gain more influence as a societal need (macro).

2.2.1.5. Place relationship

The physical environment can be defined by building characteristics, systems and rooms (windows, view, services and individual control) (Bluyssen 2014). Within the physical learning environment, the micro-level mainly concerns the indoor environmental shells; the meso-level concerns all school facility interests (functionality, maintenance, operating results, finance, etc.); and the macro-level concerns outdoor environmental shells (e.g. societal and aesthetic amenity). We have defined a structure of six physical multi-level, place-related shells as follows:

1. Shell 1: individual learners' spatial place;
2. Shell 2: class or group rooms;
3. Shell 3: indoor logistics and pedagogical features;
4. Shell 4: school-building exterior;
5. Shell 5: playground environment;
6. Shell 6: school district/neighbourhood.

This approach is rather similar to Habraken's (2000) notion of 'wholes' (types), although we have increased the number of shells by adding Shell 5: the playground.

2.2.1.6. Aggregation

Using these definitions and approach, we are able to relate a single physical shell, a problem and an actor to analyse a current problem pattern. The sequential counter-clockwise needs approach, illustrated in the model, reveals how actors' interests (actor dimensions of needs and processes) are related to the material and technological structure of learning-environment shells (dimension of life-cycle), and how they influence the whole process (shape the process decisions) (Figure 2.6.).

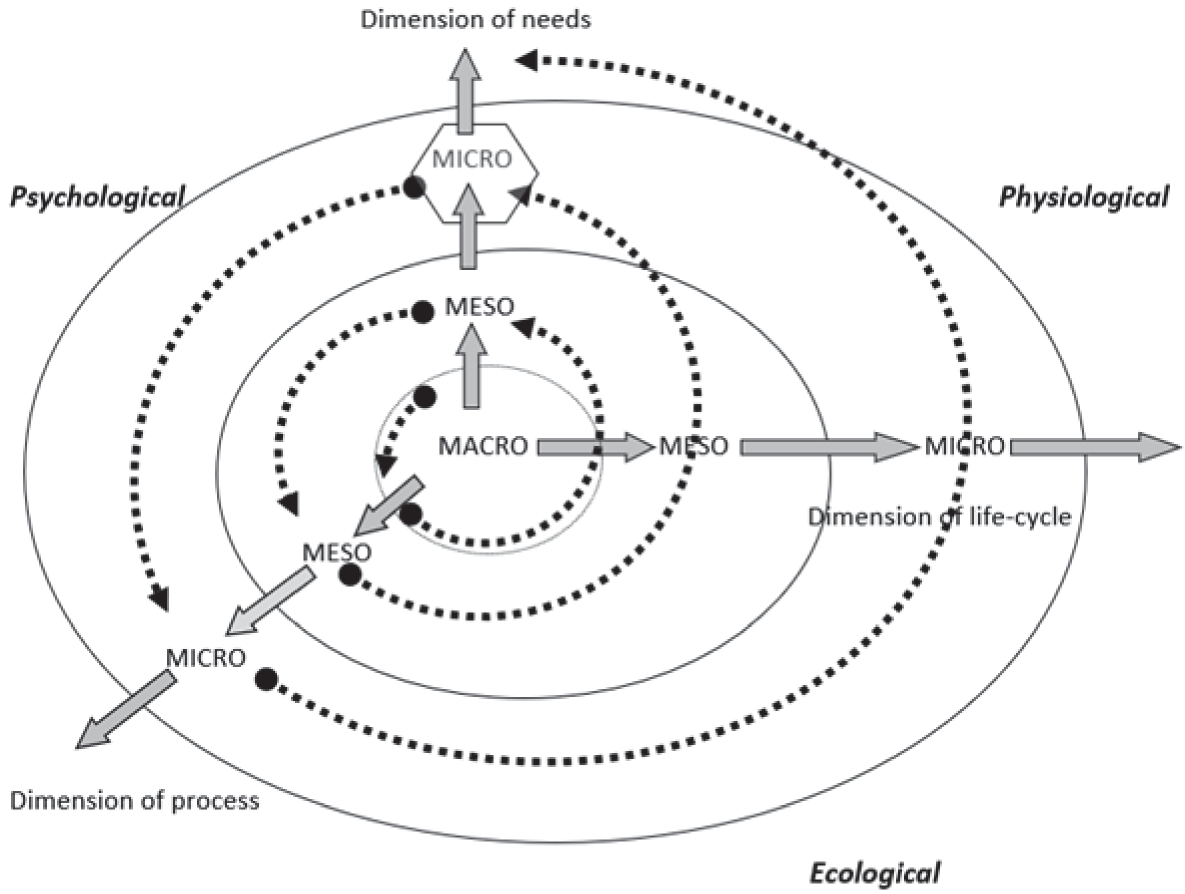

Figure 2.6. Analytic spiral model of counter-clockwise outward-moving macro-level interests.

In addition to this spiralling outwards of macro-actors' needs, the micro-actors needs are also met in the reverse direction (see New model: application of the needs-centred frame work for a new guideline, Examples 1 and 2). Thus, we are able to analyse the rational-objective antagonistic effects and the 'hidden-irrational' subjective influences.

2.2.2. *New model:* application of the needs-centered framework for a new guideline

The method generally uses seven stages: the first stage involves the analysis (the diagnosis) of a specific physical environmental problem. This first stage can also be divided into seven steps of its own (not to be confused with the seven stages in total), which identify the relationship between objective interests and subjective needs. A few samples are illustrative of this method. The first stage of the needs-centred framework (NCG) for school problem diagnosis involves the following steps:

1. determine the problem (e.g. healthy indoor environment problem);
2. determine the specific context situation (e.g. pupils' progress);
3. determine the dimensions affected (e.g. needs);
4. determine the level of the dimensions (e.g. micro);
5. determine the domain effect (e.g. physiological);

6. determine the physical shell(s) (e.g. Shell 2 – classroom);
7. determine all those involved in the spiral relationship (e.g. needs of meso- and macro actors, and processes for macro-, meso- and micro-actors).

This step-by-step method should determine the problem specifically. The subsequent steps are related to specific causal relationships responsible for the physical problem. By identifying the core human needs as the fundamental causal relationship, the effects can be described and broadly discussed (also in practice, by mirroring the actors involved in the process of changing the patterns).

When a specific problem is positioned in the multi-level model (one of the nine domain multilevel fields) and specifically determined, the diagnosis generates more insights into the specific relationships involved and their effects. This approach allows us to identify the relationship of antagonistic interests to the problem cause (which actors are involved) and the domain effects. By means of a macro-approach (counter-clockwise), in contrast to a micro-approach (clockwise), a model can be devised to illustrate the problem. By regulating and transposing the spiral relationship in a clockwise direction, rather than counter-clockwise (searching for harmony), a pupil centred approach can be emphasized. The specific description of the human needs involved reveals that they 'irrationally' shape the decisions (needs versus the effects) and this enables greater awareness through the use of the social fractal within the context of actors' needs and processes, and the time- and place-related material influences.

On the basis of this description of the various levels of human needs, and within the framework of this article, it is notable that an analysis of an individual's needs (micro) can be far more precise than meso- or a macro-group level needs. The meso-level represents an institutional actor groups' interests, which might, however, reach 'the person behind the occupation'. The macrolevel represents a rather homogeneous societal and/or government group of actors' views (considered from a cultural and sociological point of view).

<u>Illustrative diagnostic examples</u>

Two different problem examples are elaborated here:

1. Micro-level, place-related: IEQ (Shells 1–3);
2. Meso-level, time-related: rapidly changing technological innovations and pedagogical insights (Shells 4–6).

These two examples are considered to be illustrative of the extent of this NCG framework. However, we only used the first four paradoxical human needs. The inward and outward spiral models and the explanation might suggest a new pathway for solving the problem (by reshaping the process to become more harmonious) (see Figures 2.7. – 2.10. and Tables 2.1. – 2.2.). Our recommendations must be understood as interpretations based on a human-needs analysis. To begin with, this demands a good understanding of the working mechanisms behind the paradoxical emotion-centred needs and school design in practice. These two examples and the recommendations are illustrative of how we might change current patterns by making needs fulfilment the most fundamental lever for change.

Diagnosis Example 1: *the physiological problem of IEQ*

1. Problem: end-user's physiological problem of exposure to the unhealthy learning environment;
2. Situation: end-user's biological need for healthy indoor environment;
3. Dimension: needs;
4. Level effect: micro;
5. Domain effect: physiological;
6. Physical Shells:1 –3;
7. Dimensions and levels: needs (macro, meso), processes (macro, meso).

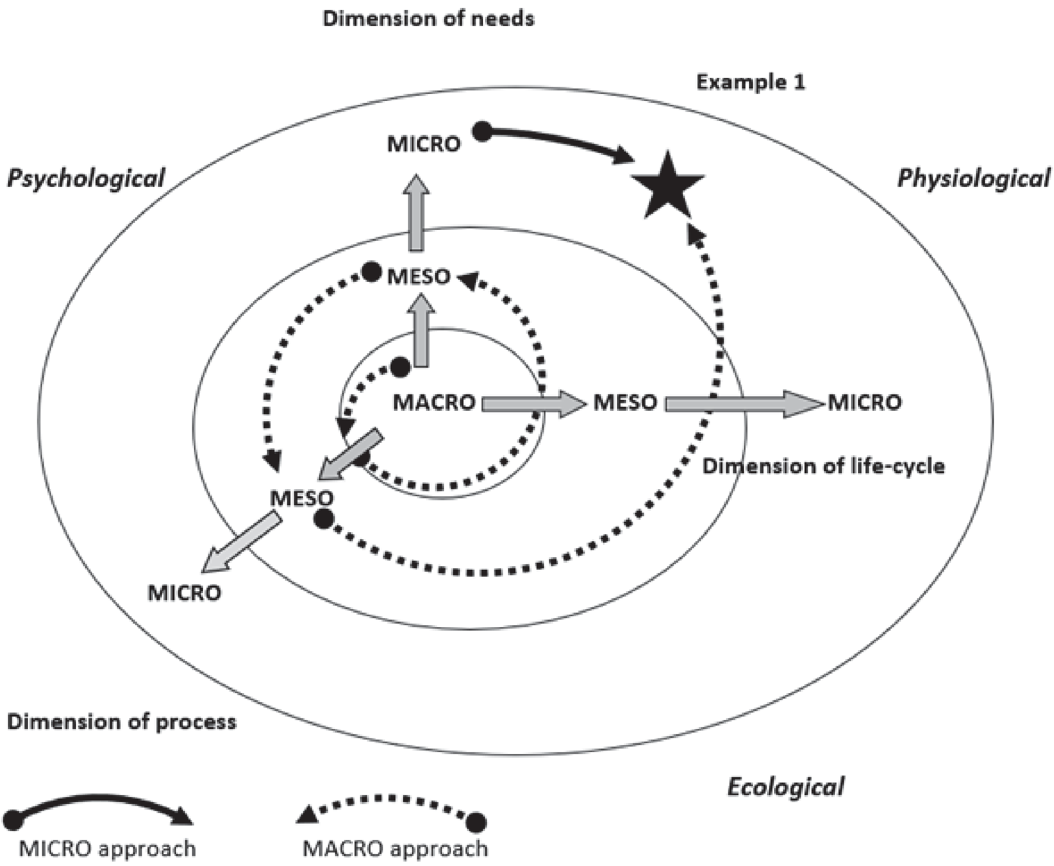

Figure 2.7. Identified antagonistic problem, Example 1.

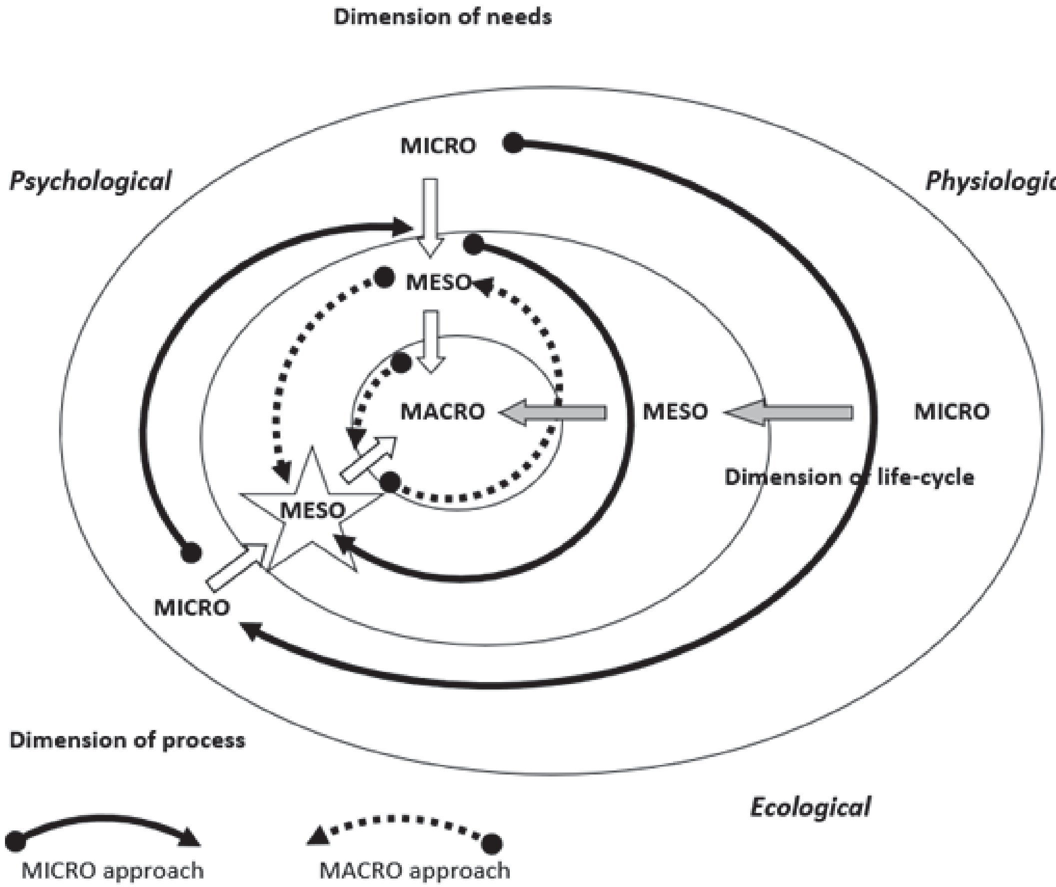

Figure 2.8. Integrated synergetic approach, Example 1.

Table 2. 1. Causal relationships between human needs and physiological effects.

Needs	Needs fulfilment (Shells 1-3)	Antagonistic effects (micro)
Certainty Macro-needs	The community's trust in governmental policy concerning healthy indoor legislation	Governments (and medical health services) lack higher standards of desired level of IEQ (indoor environment quality)
Certainty Macro-process	The high financial risks for school management boards	The decentralization of governmental responsibility to local authorities affects the IEQ in practice
Certainty Meso-needs	The local authorities' financial and political boundaries and targets	Unconscious inexperienced principals' decisions affect the IEQ conditions
Certainty Meso-process	The educational trust of experienced school-building design sector	Defragmented responsibilities (circle of blame) in IEQ processes
Variety Macro-needs	Governmental encouragement of a variety of school profiles and identity	Design complexity and IEQ failures
Variety Macro-process	New school-building legislation rules (e.g. short-term policy)	Adjustments in school-building construction affects the original calculated IEQ systems
Variety Meso-needs	New learning methods (e.g. digital methods)	Pupils' IEQ effects (e.g. radiation, electro-magnetic waves)
Variety Meso-process	Application of new technological features in education	Application of new unknown materials and technological systems affects pupils IEQ
Connection Macro-needs	Municipalities' goals for community schools and local citizens' involvement	Lack of neighbourhood interests in IEQ issues

Connection Macro-process	Increasing local autonomy and societal connectedness (e.g. by decentralized energy supply)	Lack of societal collaboration in IEQ
Connection Meso-needs	School management boards' responsibility in relation to organizational and financial targets	School management board time pressures influence the level of attention paid to IEQ
Connection Meso-progress	School management boards' connection with school-design process actors	Too much involvement with process actors might influence IEQ responsibilities
Significance Macro-needs	School-design identity and local pride	Failing architectural design affects the IEQ
Significance Macro-process	Actors involved in school-design policy and urban planning	Actors influence on design affects IEQ (e.g. sunlight effects on indoor temperature, daylight shortness)
Significance Meso-needs	New school interior design gives the school and population its own identity	The effects of special functional requirements on the IEQ
Significance Meso-process	Participation in school-design processes makes actors feel special	The danger of setting own goals over IEQ goals affects the end-users

Summary:

Societal decentralization seems to not be supported by the community's feelings of *certainty*. The need for *variety* is interwoven with complexity failures. The lack of *feeling related* to schools (note the relationship of certainty) due to lack of societal involvement is antagonistic to governmental desires. Community schools for example do not generate feeling of relatedness in the community. In the variety of school-building design and identity, increasing complexity causes indoor environmental problems. When process actors are not aware of their own significant influence, there might be no progress in IEQ and fragmented collaborations.

Recommendation:

To improve the synergetic balance we recommend a focus on the standardization of (personal) learning environments and technologically distinguished features which might generate more feelings of *certainty*. Feelings of *variety* might be reached by increasing indoor flexibility (e.g. replaceable walls). Feeling *connected*, especially referring to neighbourhood involvement, might be addressed by getting local firms involved (by local sourcing of material and energy supply, etc.). In new technological developments such as quantified-self and intelligent buildings, we identified more technological opportunities which might emphasize more *significance* in school identity, in particular school design, (incl. indoor) views (this also meets the need for growth). These recommendations might have a greater impact on current patterns (see Figure 2.8.).

Explanation of Figure 2.8:

To obtain more synergetic balance, the clockwise micro-needs pass through the physiological and biophysical domains and subsequently influence the time and place relationships in the biophysical (ecological) domain. The micro-needs spiral touches the micro-process actors (e.g. incorporating medical health care knowledge), which brings the spiral closer to the meso-needs actors. Influenced by the 'psychological' domain, these meso-needs actors describe the desired learning environments (Shells 1-3) as project-brief requirements. The counter-clockwise approach of the macro-needs actors should reset the legislation boundaries and the macro-process actors should be aware of indoor-environment quality control (see Figure 2.8.).

Diagnosis Example 2: *the biophysical problem of non-sustainable learning environment*

1. Problem: the biophysical environmental effects caused by ongoing political, pedagogical and technological changes;
2. Situation: school management boards interest in flexible learning environments;
3. Dimension: life-cycle;
4. Level effect: meso;
5. Domain effect: biophysical environmental;
6. Physical Shells:4 –6;
7. Dimensions and levels: needs (macro, meso) and processes (macro, meso).

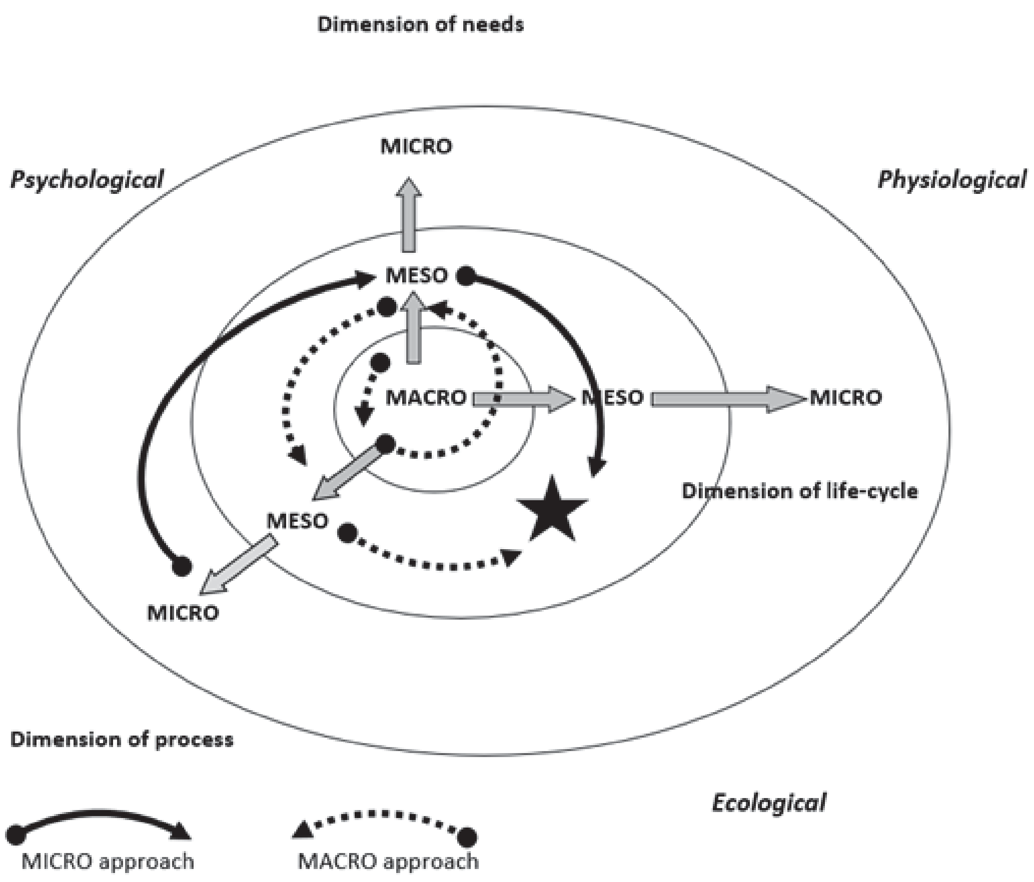

Figure 2.9. Identified antagonistic problem, Example 2.

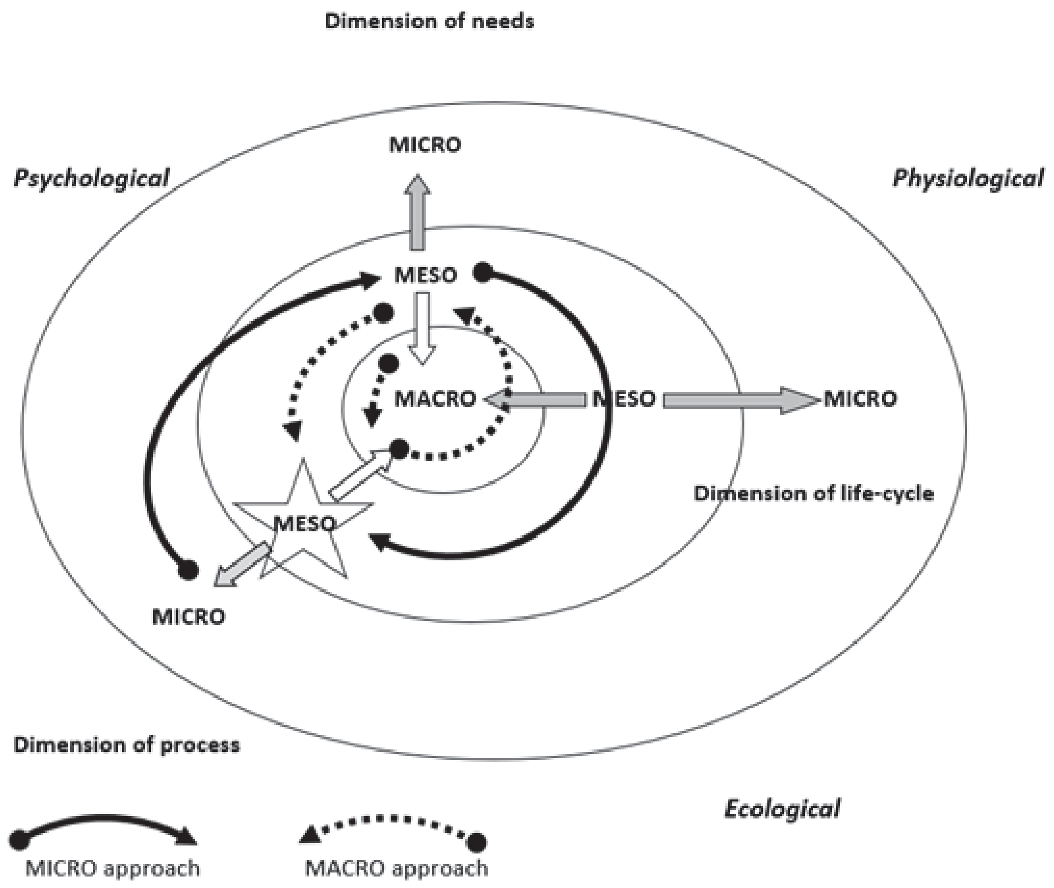

Figure 2.10. Integrated synergetic approach, Example 2.

Table 2. 2. Causal relationship between human needs and biophysical effects.

Needs	Needs fulfilment (Shells 4-6)	Antagonistic effects (meso)
Certainty Macro-needs	The local municipality's long-term integrated housing planning policy	In declining regions, lower pupil population might lead to school closure due to politically and financially driven policy to build new centrally located community schools, instead of refurbishment
Certainty Macro-process	Using sustainable boundaries systems (e.g. BREEAM score excellent)	The validity of sustainability measurement systems might generate disappointing results in practice
Certainty Meso-needs	Sustainable ambition and investment by school management boards and municipalities funds contribution	The maintenance of investment (due to lack of outright ownership) might affect sustainability conditions over time
Certainty Meso-process	Contracts of experienced building construction chain firms	Fragmented responsibility of building construction chain stakeholders might affect the maintenance stage (no connection with the school)
Variety Macro-needs	Governmental encouragement of a variety of school profiles, identities of new community schools and sustainable performances	The sustainability ambitions and investment policy of local authorities might conflict with school management desires (e.g. investment in energy reduction)
Variety Macro-process	School-design legislation improvements and changes	School-building complexity, changing legislation conflicts with execution of work

Variety Meso-needs	Introduction new maintenance methods, or outsourcing experiments	Conflicting interests between user's needs and financial responsibility of school management boards might increase 'distance' between user and management
Variety Meso-process	Application of new technological or other features in school design and environment	School-building design actors might be overly inspired by new design trends
Connection Macro-needs	Municipal school-housing policy realizes community schools and enhance local citizens involvement	Social enhancement in e.g. community schools is lacking in practice
Connection Macro-process	Increasing attention to local autonomy, e.g. decentralized energy supply	Social actors do not contribute to school-building design
Connection Meso-needs	School management boards' responsibility for social sustainability	School management board overload of tasks for enhanced sustainability
Connection Meso-progress	School management board connection with sustainable school-design process actors	Too much involvement with process actors might influence the learning-environmental needs
Significance Macro-needs	School-design identity and local pride	Failing designs affect the sustainability
Significance Macro-process	Political policy introducing new legislation rules	Long-term school design/housing policy might be in conflict with local authorities' budget planning (reserve financial budgets)
Significance Meso-needs	New local school-building design and identity	The effects of special architecture might not be sustainable
Significance Meso-process	Participation in school-design processes makes actors feel they have a special position	The danger of setting own goals over sustainable goals affects the biophysical aspects

Summary:
Societal need for *certainty* in terms of sustainability might be influenced by region-related diminishing pupil populations. Community schools are built for long-term use, in conflict with macro influences of rapid technological and pedagogical change. The need for *variety* seems to be strongly related to the need for change. The need for connection refers especially to the lack of involvement of local community with schools. The need for significance is related to the extreme design effects caused by the need for school identity (and architectural identity).

Recommendation:
We recommend a focus on the standardization of sustainable learning environments and easily substitutable technological features or even school parts, which might generate more feelings of *certainty*. The feelings of *variety* might be addressed by increasing flexibility of the physical outdoor design (e.g. replaceable facades). Feeling *connected* is especially related to neighbourhood involvement and might be addressed by increasing the involvement of local firms. In new technological developments such as quantified-self and intelligent buildings, we identified more *significance* in terms of complexity and technological opportunities (e.g. 3-D printing). Striving for more simplicity in building design and physical flexibility improves the desired functional changes (e.g. executed by local firms), contributing to meso-level interests. Due to local policy and social participation we recommend a focus on simplified building, with high technological features, incorporating specific knowledge coming from the micro-level, in terms of new 'open'-process integration of disciplines that welcomes a more synergetic approach (see Figure 2.10.).

CHAPTER 2: Problem analysis

Explanation Figure 2.10.:
To obtain a more synergetic balance, the clockwise micro-needs pass through the psychological domain in order to change the current pattern of sustainable approaches (e.g. by rapidly changing technology). The meso-needs actors incorporate the knowledge and – via the influence of the physiological and biophysical domains and time and place relationships – (e.g. total costs of ownership) bring the spiral closer to the meso-process actors (e.g. incorporating sustainability knowledge) to describe the desired learning environments (Shells 4-6) as project-brief requirements (see Figure 2.10.).

On the basis of these diagnoses and new insights, a lever for change (Stage 2) can be generated, emphasizing a willingness to change the old pattern. The problem effects (pain lever) might increase awareness of the old patterns, and the advantages of a new pattern (pleasure) might pull the lever for change and destroy the old pattern (Crisis, Stage 3). Stage 4 (building a new pattern) can begin by focusing on new aspects, such as pupil-centred (PLEs), new technologically integrated collaborative work spaces, or high sustainability life-cycle approaches. These stages will be investigated in future research (testing and anchoring the method, etc.).

2.3. Discussion

In the search for evidence-based support, we failed to find studies within this multi-level framework of needs (people), materials (planet) and processes (profit/prosperity/policy) that considered them holistically. This might be considered as a weakness. However, we did identify a human needs integration approach, although none of the articles or scientific books on the subject discussed this in any depth in relation to our multi-level framework. Our school-building design analysis employs an objective multi-level model approach in which the inclusion of subjective human factors allows the identification of existing physical problems in school-building design. The relationship between rational–technical influences on the learning environmental and 'irrational' human drivers or behavioural influences (whether conscious of unconscious) seems to provide an explanation of the interwoven physical effects. The psychological impacts seem to shape current school-building design, but sustainability performances are underestimated due to the failure to recognize intangible 'irrational' factors. In order to disentangle these aspects, we introduced a multi-level system which integrates the human factor. This approach reflects the psychological, physiological and biophysical environmental effects and should increase awareness of the process actors. Through a top-down societal and bottom-up individual analysis of current physical school-building design problems, the effects of antagonistic interests can be identified.

One main issue to consider further is the evidence-based validity of this approach and the extent to which we can rely on rather new theories from positive psychology (and the NLP based NAC method).The scientific evidence-base of NLP might still be questioned, although the evidence-base is growing fast (e.g. Stipancic et al. 2010). For example, an integrated shift towards positive psychology in Dutch psychology curriculum (e.g. Hanze University of Applied Science Groningen) might explain something about its popularity but does not prove its validity. The NAC approach is even more recent, especially compared to traditional social psychological approaches, and should be researched further because of the potential value of its results (Ramones 2011).

Thus, there is a need for more scientific research to determine the extent to which we can rely on positive psychology. The hypothesis that the 'social fractal' should be inspired by the NAC approach might be established as a proven solution in future for the crisis in school-building design. However, the introduction of this new paradigm at present remains theoretical, despite being based on remarkable similarities between various fundamental psychological theories concerning general and shared human needs. These similarities are recognized in theories of motivation, child development aspects, environmental psychology and evolutionary psychology and many other theoretical human-needs approaches. We expect that these behavioural insights (by increasing awareness) might lead to some improvements in school-building design, insofar as this core paradoxical system of human needs is developed into a step-by-step method, inspired by positive psychology. However, it should be noted that this will only occur when the actors are willing to change existing patterns.

Although there is a crisis in building construction processes and different roles for traditional stakeholders, we did not find evidence-based studies in this field on the possible role of human needs. The model and framework might provide an insight into how human needs interact in antagonistic fields of interest and how they shape process decisions. While there are a few examples in practice, in which we find companies training their employees to prepare them for collaboration in future processes, it may prove difficult to overcome current patterns in traditional school-building design processes when identity aspects play such a huge role (e.g. architects and the role of designers). We suggest that current antagonistic approaches to the fulfilling of the needs of various actors should be replaced by a more synergetic pathway. Anticipating future developments, new technological opportunities, new pedagogical insights and new sustainable school-building design demands, it might be a step too far and perhaps a little too complex to predict a more robust school-design framework that relies solely on a human needs fractal elaborated in a number of steps. It is a fact, however, that there is a trend towards new PLEs, quantified-self and intelligent building concepts that will have a role in the near future. From a philosophical perspective, it can be argued that post-humanistic approaches fulfil the need for growth and might stimulate new applications, even if they challenge the need for certainty of their opponents (a biological evolution of technology and psychology?). It might be a challenge to merge these developments with time-related insights into school-building design, especially considering the need for growth in this perspective. Here we come to the preliminary conclusion that there is ground for using core paradoxical human needs to predict future technological and sustainable growth.

The framework developed here offers a method that could be used to change current school building design patterns, taking into account the rational and 'irrational' factors involved, so as to overcome the problems. It suggests new clues for solving the crisis by means of a new paradigm. Given the NCG framework as a potential future guideline, the few examples provided here should be expanded and tested in practice to determine their generalizability. By developing the framework into an objective guideline manual that can manage multi-level needs, processes and a sustainable learning environment – within current boundaries and expected changes in the future – the new paradigm might generate new insights that allow us to reflect on the subjective influence of all of the current actors. We assume that there is an interesting clue and theoretical ground for changing current school-building design approaches using a fundamental human needs approach, which might even have wider applicability (NCGx).

2.4. Conclusion

The main aim of this article was to deliver a hypothetically generated integrated framework for a needs-centred guideline for primary schools, based on more awareness of cyclical processes and through a conscious integration of human needs. The complex antagonistic effects of current design patterns and the psychological impacts might contribute as levers for change, building new pathways which might achieve more positive responses, generating more synergetic approaches with new intelligent technology, and a greater awareness of the importance of human factors. The framework also has the potential to contribute more broadly by helping to define the fundamental parameters of the learning environment and in turn allowing us to better anticipate future developments in PLEs. While the question posed in our title might not yet be answered convincingly, future research will develop our approach into more applicable guidelines.

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Chapter 3
SOCIAL INTERESTS

An analytical perspective on primary school design as architectural synthesis towards the development of needs-centred guidelines

ABSTRACT

Primary school design is balancing between end-user needs and societal interests, and between traditional and innovative approaches. In current approaches, an unbalance affects end-users' performances and obstructs innovative school-building design. The institutional system of design should not only be more aware of adjusting the quality design indicators to end-users, but they should actually do it in combination with the increasing need for more innovation in school-building designs. Present guidelines emphasize objective rational societal and traditional interests but underestimate the subjective essences of individual enduser needs and the abilities of intelligent school buildings to meet important requirements for present and future learning environments. Based on universal human needs and dynamic mechanisms relationships, this article addresses a number of reasons that cause these mismatches. We present a theoretical analysis to establish Needs Centred Guidelines for primary school design as a methodological tool to improve the balance between the societal and end-users' needs, and to give more insight into underlying patterns in design processes. The guidelines are based on a variety of end-user psychological, physiological and bio-physical needs. This article explains how this analytic approach contributes to the attention for end-user physical learning environment needs and to innovate school design.

Keywords: User experience design; users-needs; personal control; adaptability; environment and behaviour

Additional information chapter 3	
Authors	R.de Vrieze[a], H.C Moll[b]
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[a] Hanze University of Applied Sciences – Research Centre for Built Environment NoorderRuimte, Van Doornveste, Zernikelaan 11, 9747 AS Groningen, The Netherlands.
[b] University of Groningen - ESRIG Energy and Sustainability Research Institute Groningen, Centre for Energy and Environmental Sciences, Energy Academy Building, Nijenborgh 6, 9747 AG Groningen, The Netherlands.

3.1. Introduction

Primary school design is balancing between end-user needs and societal interests, and between traditional and innovative approaches. Although every end-user has his own physical learning environmental preferences, due to different age, gender and personal characteristics, current toolkits and guidelines are mainly focused on one-size-fits-all group processes. For example, the Dutch foundation RuimteOK recently established a broad consensus-based work document 'Het Kind Centraal' [the child positioned in the centre], meant for school management boards (RuimteOK 2014). It prescribes the design quality indicators, and it distinguishes subjective and objective design quality criteria. The Scottish Government established the 'Building Excellence' guide (2007), within which 'exploring the implications of the curriculum for school buildings' (TSG 2007). The British Priority School Building Programme gives school communities, designers and contractors a standardized baseline design as a starting point since the Building Schools for the Future programme was scrapped in 2010. The Learning Environments Evaluation Programme (LEEP) aims to produce instruments and analysis that inform school leaders, researchers, policy-makers and others about how investments in learning environments, including the physical learning environment, translate into improved education, health, social and well-being outcomes, leading to more efficient use of education resources (OECD 2016). British Government advisor Commission for Architecture and the Built Environment (CABE) published 'Creating excellent primary schools – a guide for clients' (CABE2010a) giving detailed information about current views on primary school design. In particular the CABE toolkit 'Our Building Matters', meant for teachers, states the attention for subjective issues within pupil experiences: 'What is your favourite part of the building and why? How do these spaces feel?' (CABE 2010b). It is remarkable is that all guides lack an analytical holistic approach to assess whole school environments that meets a good balance between individual needs, group needs, management board and institutional needs, and societal needs.

End-users are not direct stakeholders and therefore often neglected. To reach an architectural synthesis through only dialogue of direct stakeholders and experience, which is the normal means adopted, is a shortfall for end-users' personal learning environment (PLE) requirements. There is currently a debate about the societal needs, for example carbon footprints, and a growing trend towards respecting the needs and responsibilities of the individuals who occupy and use buildings (e.g. Clements-Croome 2014a). The centred position of pupils' personal aims, the responsibility for acting, self-steering, autonomy and reflection, are new important ways for redesigning education (e.g. Dam, Timmermans, and de Wit 2010). More attention for personal needs to adjust individual learning environments is identified as a new trend (e.g. van Wetering & Desain 2013). Future scenarios (forecasts) and possible future scenarios (foresights) need a new point of view of innovation and transition networks (Rademaker, van de Linde, and Hazeu 2011).By analysing the sustainability rating no significant overall relationship to the attainment is found and that any improvements in attainment continued only to the third year of occupation, following which it deteriorated considerably (Williams et al. 2015). The present quality of guidelines gives designers much room for own interpretation of interests, which might contribute communities' cultural and identity values, it certainly neglects the complexity of subjective end-user needs. For example, new technology that contributes sustainable buildings might conflict totally with the psychological and physiological needs. Kerr (2013) states that buildings that do not fulfil the (ideal) brief leave occupants intellectually, physiologically, emotionally, behaviourally and spiritually unstimulated (Kerr 2013). A shortness of individual adjustments and controlled PLEs is also caused by insufficient attention to age and gender differences (Schellen 2012). Ackerly, Baker, and Brager (2011) state, for example, how the need for autonomous individual control and fresh air experiences conflicts with rational technological solutions: 'if windows are automated for natural ventilation, the building design loses the comfort benefits, amenity, appeal and robustness of manually-controlled windows' (Ackerly, Baker, and Brager 2011). In other words, a common need for individual occupants is the ability to open a window for fresh air, for breathing colder air, or feeling just the wind blow, which has obviously not the same consequences as the societal and institutional need for energy saving. Using heat recovery systems in thermo-neutral conditions has bio-physical consequences, such as a significant correlation between young men with overweight (Marken Lichtenbelt et al. 2009).

A number of causes are recognized by the governmental actor analysis report (RVO2014).In policy individual needs are also still considered to be more subjective and societal needs more objective (Tiemeijer, Thomas, and Prast 2009). School design architect Herzberger (2008) states that the school-building design has been approached long too uncritically (Herzberger 2008). Current traditional school design establishment ignores the call for integrated school-building design, it lacks (the understanding of) an educational vision, and fails to translate it into material spaces (Mumovic 2015). Besides the need for sustainability, healthy, technologically aware, intelligent buildings should meet the needs of occupants, and should be flexible and adaptable to deal with change (Clements Croome 2014b). The governmental decentralization should stimulate growth and educational freedom of local authorities, but a growing unbalance of 'trust and control', within an increasing emphasis on legislation-controlled policy, has been identified: 'they want education to be strong, secure and predictable, and want it to be risk-free at all levels' (Biesta 2014). The problem of lacking end-user individual needs, have not been addressed for a long time by assimilation various sub-disciplines, but instead, still by the run to the hard technique of construction for those problems where soft techniques are needed (Bax 1977). School design always had a societal position and no other building architecture has ever exposed its architectural design to society (Herzberger 2008).

Architects should converse more with pupils to know their thoughts about their ideal school design (e.g. Haren and Willemstein 2015). Despite the use of the different consensus-based institutional guides for briefs, it is not expected that they guarantee a stable balance of societal, institutional and end-user interests for physical environmental learning environments. The subjective and objective quality design indicators should be balanced better especially by considering the core psychological human needs such as recognized many times before. For example, Gee (in Oblinger 2006) considered, within their described human-centred-design guidelines, the universal human needs and learning principles to be the first priority (in Oblinger 2006). Bluyssen (2009) states: 'It is very important to know the needs of occupants of certain indoor environments in order to be able to set the performance criteria of such an environment' (Bluyssen 2009). Oseland (2009) describes the value of the impact of psychological needs on office design by summarizing the main psychological theories (personality and motivation theories, environmental and evolution psychology) that have implications for the design and management of successful workplaces (Oseland 2009). Topics such as the integration of human needs in the design of primary schools are recognized as a main issue of affecting pupils' learning performances (Mumovic 2015). The use of interactive devices already can increase the indoor quality control of ventilation, thermal comfort, natural light, noise and privacy (Raymond and Bornik 2009). The aim of the research was to achieve an architectural synthesis from a theoretical approach, in particularly focused on primary school building end-users. The main reasons for this research is the need for a holistic approach to assess whole school environments, and an architectural synthesis by means of a dialogue does not guarantee a sufficient client brief. We assume that human needs based underlying pattern relationships should become the anchor for intelligent buildings to facilitate the occupants optimally and to stimulate school-building innovations. The continuums of societal and end-user (and individual) relationships with physical learning environments, and within it the social and physical interactions, are considered from a multi-level scaled perspective of different interests. This approach delivers a recipe to achieve a theoretical balance of the multi-level scaled requirements based on a full assessment of six mutual and hierarchical human needs, their relationship with six defined physical learning environmental shells, and seven principle-based characteristics. Two illustrative examples are elaborated to consider the value of the theoretical approach, and show how quality design indicators for end-users and individuals can be established in relationship with their learning environmental shell and underlying involved characteristics. These elaborated examples relate the theoretical approach to educational perspectives using teacher interviews. The developed model of Needs-Centred Guidelines (NCGs) for primary schools is tested for practical application for primary school design by the Gaudí's Parish Schools of Sagrada Familia.

3.2. Method

In the continuum of societal and end-user interests, such as institutional associations for education, local governments and communities, school management boards, and end-users, such as board members, teachers, pedagogues, parents and pupils. These pupils also can be distinguished by high screen pupils, and low screen pupils with specific disabilities, impairments or special personal characteristics, which state together a mixture of interwoven subjective and objective interests. This dynamic mechanism involves a dynamic continuum of substitutional and interacting factors to fulfil emotionally the needs individually, by social and physical (psychological, physiological and biophysical) interactions. For example, when pupils are totally intrigued by what the teacher educates, the environment might not be so important at all. When the pupils are doing concentrated work the learning environment should support this as much as possible. This necessitates a systems thinking approach to distinguish comprehensively the individual different characteristics and underlying patterns. For example, end-users' psychological, physiological and bio-physical differences should be understood by their underlying needs relationship. Therefore a distinction is made by the two extremes of the continuum between society and end-users, and subsequently between individuals themselves. A focus on these continuums of stakeholders' interests concerns a search for more balance between societal and end-user interests, and between end-users and individual interests. Specific interests between these extremes, such as institutional interests, are considered to be also societal. A first considered continuum to balance is made by the social interaction between societal versus end-user needs, which supports a heteronomous approach of the learning environment. A second considered continuum to balance is made by the social interaction between the end-users and individual needs, which demands an autonomous control of the learning environment. A third considered continuum contains the interaction between end-user group interests and the physical learning environment. A common used pattern considering the pupils and their learning environment as 'one-size-fits-all', influenced by societal (heteronomous based) interactions, which adheres a heterogeneous control of the learning environment. A fourth considered continuum contains the physical learning environmental interaction between end-user needs and the physical learning environment, influenced by individual autonomous needs, which adheres a personal control of the learning environment. Individuals cope individually with their learning environment which supports the idea for seeking the sum of the personal optimal activation levels and control of the PLEs (see Figure 3.1.).

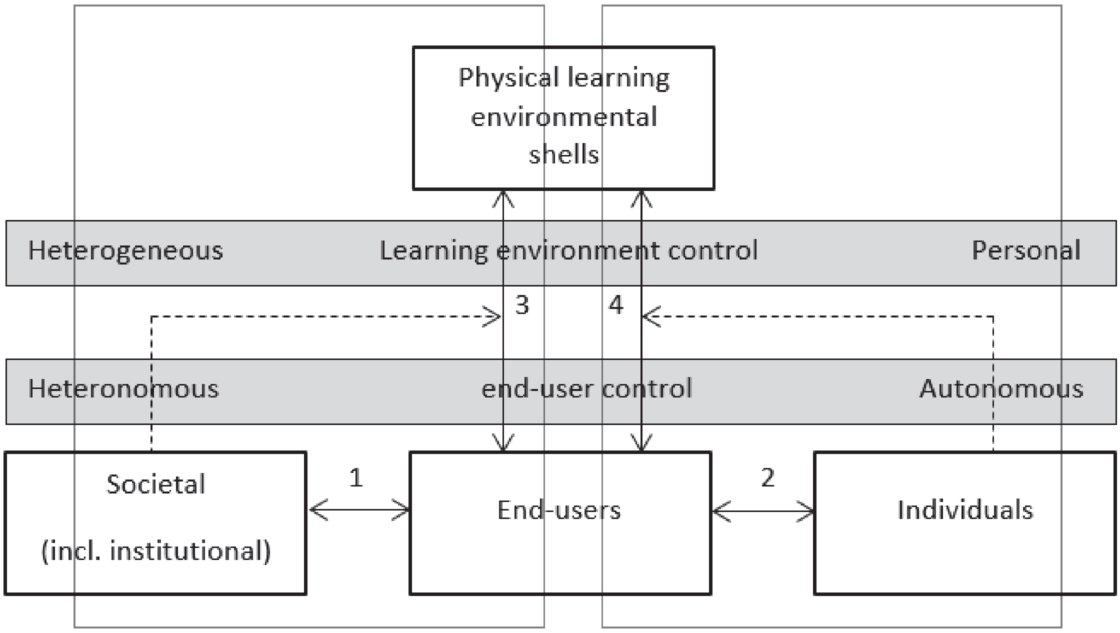

Figure 3.1. Four continuums of social and physical relationships.

These four continuums consider two social and two physical environmental relationships containing the next interaction relationships:

1. Social relationship between end-users and societal stakeholders;
2. Social relationship between end-users and individuals;
3. Physical relationship between end-users and the learning environmental shells, influenced by societal needs;
4. Physical relationship between end-users and the learning environmental shells, influenced by individual needs.

The four end-user related continuums have been considered socially and physically by multi-level approached extremes of societal [1] and individual [2] end-user interactions, by the heteronomously and autonomously related physical learning environment. Vischer (2008) distinguishes user-centred theories of the built environment from an environmental determinism approach, such as 'what causes users' behaviour?', and from a social constructivism approach, such as 'what determines human behaviour?' (Vischer 2008). Vischer (2008): 'what is clear, however, is that in spite of the unrealistic positions of each of these multi-level approached extremes, any user-centred theory of the built environment is likely to be located somewhere along the continuum between them'(Vischer 2008). Vischer (2008) also states: "*human behaviour is influenced by the built environment in which it occurs but it is not determined by it; and it is clear that in a given situation, building users' behaviour is influenced not just by the space they occupy but by their feelings, intentions, attitudes and expectations as well as by the social context in which they are participating*". (Vischer 2008)

In general, physical learning environment and end-user interactions are approached in school design processes heterogeneously. Mainly societal actors use heteronomous approaches as 'one-size-fits-all' [3], such as the generic control of the room temperatures. Individual interests are represented by children personal needs, as well as teachers or other pedagogues [4], and shows the differences between age, gender and personal characteristics.

The theoretic analysis of societal and end-user needs, and individual needs, to bring more balance within this continuums within which multi-level scaled perspectives of societal, institutional, end-user and individual interests can be considerate separately. To establish new guidelines as NCGs for primary schools, a recipe is presented that involves a heterogeneous relationship and a personal relationship that both distinguishes end-users' relationships with the physical environment by considering multi-level scaled, six mutual-related human needs, six physical learning shells and seven characteristics. The used method accumulates heterogeneous group needs and personal human needs characteristics, to establish a number of coherent principles by the human needs based qualitative and quantitative principles of [1] physical environment influence relationship; [2] psychological, physiological and bio-physical relationships; [3] dynamic balances relationship and [4] paradox relationship. A step-plan method has been applied which uses three steps to distinct the societal needs, the generic end-user needs and the personal needs, by [1] separating the end-user needs from the societal needs [continuum 1]; [2] separating the individual needs from the heterogeneous group of end-user needs [continuum 2]; [3] using the principles within the focus on four generic characteristics in a heteronomous-heterogeneous perspective [continuum 3] and [4] using the principles within a focus on three personal characteristics in an autonomous-personal perspective [continuum 4].

3.2.1. The human needs based qualitative and quantitative principles

3.2.1.1. The human needs and their physical environment influence relationship

A hexagonal model of universal human needs, based on different human needs theories, illustrates this, presented by De Vrieze and Moll (2015). De Vrieze and Moll (2015) elaborated a needs-centred framework inspired by a positive psychological approach of coaching systems (e.g. NLP, NAC) which led to a new paradigm to solve the process related physical problems in primary school-building design, such as indoor climate quality problems, by analysing underlying behavioural-related patterns. The offered model includes six core needs, which are related to the immaterial and physical material school design environment experiences to explain the origin of current school design problems. This principle follows the pathway of hierarchical, cumulative and mutual related pattern to fulfil the needs alternately, inwards and outwards, and upwards and downwards. The needs are divided by (1) certainty; (2) variety; (3) connection; (4) significance; (5) contribution and (6) growth (see Figure 3.2.).

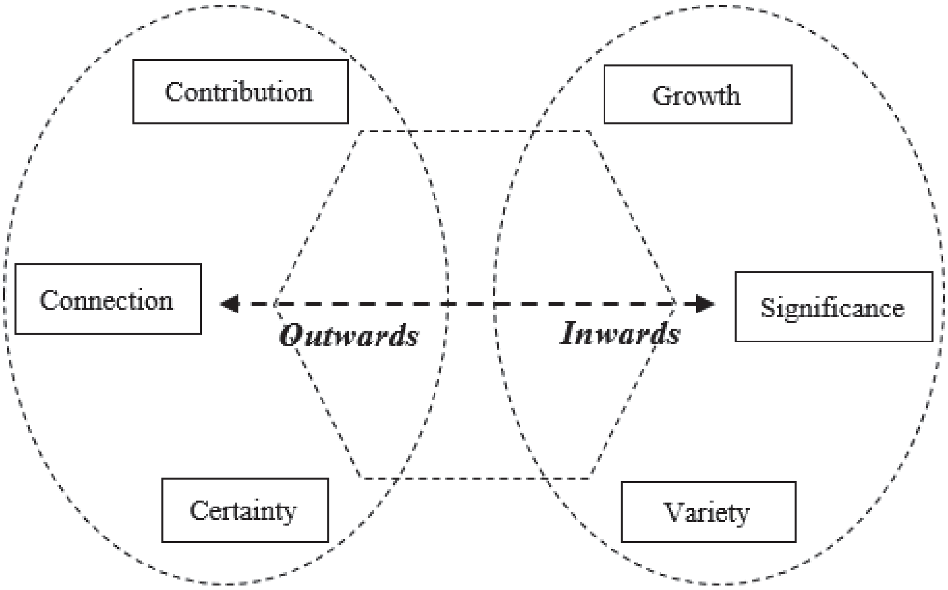

Figure 3.2. Hexagonal model of outward-directed and inward-directed human needs (see De Vrieze & Moll 2015).

Based on the article of De Vrieze and Moll (2015) a number of human needs characteristics are elaborated and brought into relationship with the physical environment. The hexagonal model mechanism as illustrated in Figure 3.2. consists a dynamic of and mutually related pattern of six human needs (De Vrieze & Moll 2015). This patterns, called a social fractal, seems to have a self-similarity characteristics identifiable from individuals to all upper actor levels, for example, peer groups, parents, teachers, institutional actors, community and societal groups. This social fractal is related to six physical learning environmental shells, such as defined by De Vrieze & Moll (2015) by: (1) desk; (2) classroom; (3) corridor; (4) exterior design; (5) playground and (6) neighbourhood. The continuum of all actor levels create social and physical experienced interactions with the learning environmental shells and a certain emotional impact level of satisfaction by needs fulfilments per actor and per shell. For example, end-user physical material experiences (e.g. surface temperature of learners-desk material) and social immaterial experiences (e.g. the teacher–pupil relationship) both contribute to the fulfilment of one, or more, of the six human need(s), within a specific physical learning environmental conditions. All these experiences together are intervening into the continuum of societal and end-user interests, socially and physically, and relate to a certain appreciation of the physical objective learning environments value as an intra- and intersubjective experience. The dynamic mechanism of human needs is the first principle we used to generate the guidelines.

3.2.1.2. The human needs and their psychological, physiological and bio-physical relationships

Within the physical environmental impacts on end-users, the influences of psychological, physiological and bio-physical needs and their relationship with the needs are considered to be very important. For example, to consider within societal and end-user multi-level scale perspective of interests the societal strive for using new technology in education (e.g. using WIFI in school buildings) might be a contradiction with end-users bio-physical needs.

Bio-physical (bodily) needs and physical environment adjustments are main issues in school design to consider because of peoples' unawareness long-term exposure effects, such as (1) natural needed experiences (e.g. sunlight for vitamin D, daylight for Myopia prevention); (2) unwanted natural experiences (e.g. fungi, polls); (3) artificial unnatural material experiences (e.g. furniture, computers) and (4) artificial unnatural immaterial indirectly experiences (e.g. radiation, toxics and fine dust particles).

Physiological needs, such as end-user sensory reception and perception, interrelate with natural bio-physical needs (e.g. sunlight radiation). Pupils' performance is influenced by a brought range of physiological needs, such as acoustics, aesthetics, colours, lighting and thermal environment preferences, and it will affect their performances in terms of behaviour, health and well-being. The relationships between individuals and their environments are crucial in determining how they feel, perform and interact with others (Cooper, 2015). Sensory stimuli are very relevant for hedonic experiences as well as for a sustained well-being or enriched enforcement (Frijda 1986). Individuals differ by (or by combinations of) visual, auditory or kinaesthetic experiences preferences (e.g. Rittelmeyer 1994).

Psychological needs are interrelated to the bio-physical and physiological needs. For example, Oseland (2009) suggests that some guidelines (the case is offices) should be evolutionary psychology based to meet basic psychological needs such as comfort, safety, security and sense of belongingness (Oseland 2009). Oseland (2009) states: 'person's psychological processes are probably more adapted to living on the African savannah than they are to working in offices' (Oseland 2009). Oseland and Hodgeman (2015) state that 25% of the impact of noise on dissatisfaction is physical related, but more than 50% is psychological (Oseland and Hodgeman 2015). A variety of theoretical approaches describe this continuum relationships of psychological, physiological and bio-physical interactions (e.g. Evans and McCoy 1998; Korpershoek 2011; Altomonte, Rutherford, and Wilson 2014). Evans and McCoy (1998) suggest that certain attributes are especially important to healthcare settings, such as stimulation, coherence, affordances, control and restorative qualities (Evans and McCoy 1998). Evans and McCoy (1998) pointed out that also privacy, complexity, exploration, place identity legibility and safety contribute to an integrated approach of psychological, physiological and bio-physical determinants (Evans and McCoy 1998). Korpershoek (2011) used three theoretical pillars bearing the premise that there is an interaction between the physical room and the psychological, physiological and bio-physical health of the people inside. At a personal level, actions can be behavioural (e.g. adjustments), physiological (e.g. acclimatization) and psychological (e.g. habituation) (Altomonte, Rutherford, and Wilson 2014). Barrett, Barrett, and Zhang (2015b) state that it is necessary to think beyond just comfort and to include the impacts of spaces on health, well-being and productivity together, all within the challenging context of energy constraints' (Barrett, Barrett, and Zhang 2015b). This variety of theoretical approaches describe thus a continuum of psychological (e.g. cognitive), physiological (e.g. sensory) and biophysical (e.g. bodily), relationships (see Figure 3.3.):

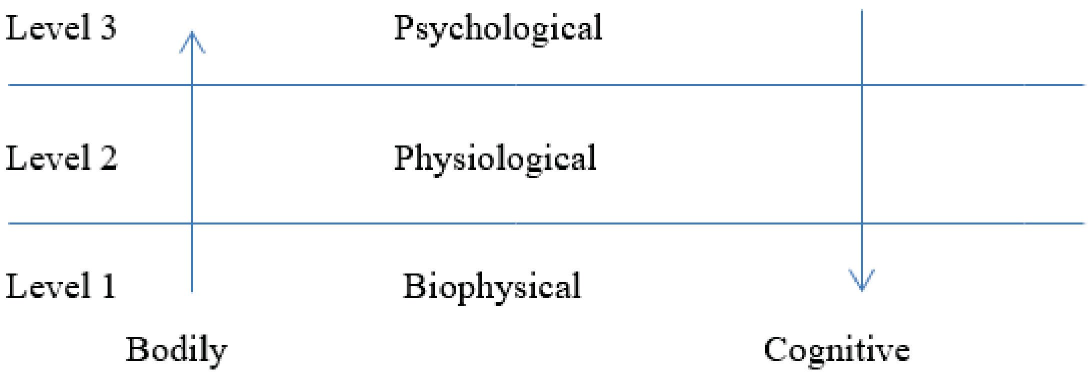

Figure 3.3. The related domains of bodily, sensory and cognitive satisfaction.

These examples state how human needs and psychological, physiological and biophysical domains are hierarchically related. The interrelated fulfilment of human needs by psychological, physiological and bio-physical satisfaction is used as a second principle.

3.2.1.3. The human needs and their dynamic balances relationship

The dynamic pattern of human needs (principle 1) and the biophysical, physiological and psychological-related domains (principle 2) are interrelated connected, as a dynamic mechanism of needs satisfaction, socially and physically. The need for certainty is more profound than the need for variety, referring to the children development psychology, but these needs are also collaborating together. This pair of needs, certainty and variety, are in hierarchical perspective more core positioned, than the upper-related needs for social connection and significance (see Figure 3.4). These latter two needs are subsequently more centre-pointed than the upper needs for contribution and growth. Besides this development-related dependency of children's emphasis for lowest needs for certainty and variety, a certain force between all these needs might be seen an inwards directed which keeps these needs together, and a certain force might be considered as being more outwards directed. The relationship of the qualitative needs is considered to be a 'law of nature' within quantitative influences. The potential of this analytical perspective to reach an architectural synthesis by using an underlying 'code' might impact current approaches of school-building design according to Mock and Wernke (2011) when they state, that we now know that the physical, biological, social and even the economic universe is not random, and that we are beginning to determine just what that underlying 'code' is (Mock and Wernke (2011). Reading (1994) stated, for example, that a rule of nature is minimalize the energy as dynamic behaviour characteristic of the Golden Mean (Reading 1994). When there are certain natural ratios of development stages related to differences needs, such as known from children development psychology, these fractal pattern of human needs ratios might state that the third principle of the dynamic balance of needs can be formulated quantitatively such as by the golden ratio. The golden ratio is used as a 'fictive' approach, which cannot be validated as a method to calculate analytically the impacts, but it can illustrate the different values of needs. The 'golden ratio'

Fibonacci sequence values [55/34=ca. 1.6] determined by the surface areas numbers {55+34+21+13+8+5} relates to the percentages {40+25+15+10+6+4}. The two perspectives of societal and end-users are illustrated with some examples by their different relationship with the physical shells. The values are included which states that the need for certainty is a factor 4,while the need for variety is less than 3 (see Table 3.1.).

Table 3.1. Example of the dynamic balance of human needs.

Human needs balance quantification table of physical environmental impacts			
Social system factor	**Percentage terms of ratio and weighting factors to balance**	**Examples of intra- and intersubjective experiences**	
		Societal (exterior, playground, neighbourhood) The building give feelings of:	**End-users (workplace, classroom, layout)** The building rooms give feelings of:
Certainty	55/136 = 40% = 4	Being part of local community facilities	Easily accessible, and easy to overview
Variety	34/135 = 25% = < 3	Contributing to a variety of local architectural design styles	Diversity (size, form, visual diversity, temperature diversity et cetera)
Connection	21/136 = 15% = > 2	Connectedness to the community (easy to access) and, for example, by local used materials	Connectedness (clusters of pupil ages year groups)
Significance	13/136 = 10% = 1	Uniqueness, being proud of the design and facility performances	Being special (every year its own colour)
Contribution	8/136 = 6% = < 1	Contribution to the liveability	Contribution to learners community
Growth	5/136 = 4% = < 1	Being flexible enough to grow with the changes, and adaptive to incorporate future changes	Growth by grading to higher group (room) and accessibility of getting autonomy in individual learning

The third principle of the dynamic balance of needs can be stated quantitatively and qualitatively by the golden ratio and the balance of inwards and outwards directed needs.

3.2.1.4. The human needs and their paradox relationship

The human needs (principle 1), the three domains, (principle 2), the dynamic balances (principle 3) collaborate together like scanning the individual experiences to gain inner balance by fulfilment of the needs. Referring to Barrett et al. (2015a) they state that the physical part of influences is only16% of the variation in pupils' learning progress and can be explained by the physical attributes of the classrooms (Barrett et al. 2015a). The summary report 'Çlever Classrooms' of the Holistic Evidence an Design (HEAD) project (Barrett et al. 2015c) is used to distinguish the needs relationship quantitatively. The interchangeability occurs apparently by the fulfilment of the intra- and intersubjective needs, sociologically by individualization factors (e.g. flexibility, ownership, connection), physiologically by sensory experiences (e.g. complexity, colour), and also by naturalness factors (e.g. light, air quality, temperature), which comes close to the identified factors by Barrett et al. (2015a, 2015c), but in our analytical research the parameters are distinguished by means of identifying the underlying 'code'. Barrett et al. (2015c) describe three levels of Naturalness, Individualisation and Stimulation, Appropriate levels (Barrett et al. (2015c). From a human needs theoretical approach of relationship, we describe four paradox multi-level scaled applicable direction patterns are recognized, because of the fractal self-similarity relationships we add social factors (Connection) as a separate group instead of part of the personal factors (Individualisation):

1. the development factors (e.g. hedonic experiences of motivation) as stimulation appropriate levels of upwards directed needs, such as the need for growth (e.g. intelligent building design).
2. the social factors as outward-directed needs, such as the need for social connection (e.g. identity of a community, or school dress);
3. the personal factors (characteristics) as individualisation levels inward-directed needs, such as the personal need for significance (e.g. special school-building design or someone's identity);
4. the natural(ness) factors (experienced situational circumstances) as downward directed needs, such as the need for certainty (e.g. natural materials or structure);

Support for the paradox mechanism between these four directions is also found by environmental psychology, for example by Carr (1967). Carr (1967) describes an inwards and outward-directed polarity of needs and the related tensions in between (Carr 1967). An up- and downwards directed polarity is identified by Heerwagen (1998), describing four elements: (1) cognitive effectiveness; (2) social support and (3) emotional functioning; and (4) physical function (in Oblinger 2006). Within these four elements four polarities and paradox mutual relationships are considered:

1. the cognitive effectiveness, considered as upwards directed psychological need for growth and contribution;
2. the social support, considered as outwards directed need for social connection (and partly certainty and contribution);
3. the emotional functioning, might be based on general fulfilment of needs emotionally impacts, considered as inward-directed need for self-esteem, or as a need for significance (and partly variety and growth);
4. the physical situational function, considered as a natural factor of a downward directed need for certainty and variety.

Within this field of paradoxes, the design preferences also can be recognized (e.g. biophilic design vs. hi-tech design, or societal design vs. PLE design).The balance within the social fractal between the needs for certainty and growth, and connection and significance might also be considered as a continuum due to the continuing search for balance. From a sustainable point of view and considering the fast changing world, a strive for using more intelligence in buildings can be recognized well.

Hence, the balance-point seemingly shifts upwards from a meta point of view considered. That also might means that there is more confidence in current technology. But although the world is changing fast, traditional beliefs will always remain. For example, 'is the classroom probably one of the ones that will remain with schools until last' (Brasters, Grosnevor, and del Mar del Pozo Andrés 2011) as a need for certainty stated. Cyber-psychology, however, forecasts the new learning environments that promotes virtual reality effects, and attaches our senses determined by emotions, thinking and behaviour (e.g. Uhls, Zgourou, and Greenfield 2014). Current and future developments of augmented and virtual realties, ubiquitous learning, gesture-based computing and blended learning, might give a glimpse as this growing need for growth, although, still kept in harmony within the relationship of human needs, such as by the need for certainty by using natural elements into the design. Hence, from a meta perspective, future education and new physical environments shift from traditional design to sophisticated technology design (e.g. Education-20252015).This slowly time shift towards technology driven developments, also in architectural design already slowly incorporated, has recognizable characteristics with the social fractal of needs. The current perception of E-learning developments, influenced by societal developments and technological innovations, such as using wearables in classrooms in order to measure the bodily needs considered heterogeneously and individually, might change totally the general view of technology enhanced learning (Rubens 2013). Mumovic (2015) suggests that research efforts in future should have several distinguishing features, which would be enable research community to deliver a step change in the current building design research practice (Mumovic 2015). Clements-Croome (2014a) refers to wireless sensor networks, smart metering, the influences of Internet of Things, and to the expand of the traditional design and management team to include emerging sustainability specialists (Clements-Croome 2014a). This fourth principle states the paradox relationship of needs mechanism and the relationship with future developments.

3.2.2. The step plan of continuums

3.2.2.1. Separating the end-user needs of the societal needs

This step, especially meant as an assessment to gain more awareness of end-user needs, exposes the difficultness of current approaches to define the design quality indicators, within which the interwoven mixture of multi-level stakeholder interests can be identified well. The elaborated example illustrates how to separate the multi-level scaled interests from the end-users (see Table 3.2.).

Table 3.2. Example of distinction end-users' needs and societal interest.

No.	DQI illustrative example: the façade – window frames in classrooms
1	Identify the physical shell characteristics: ➢ The façade - large window frames in classrooms; Category: Exterior design expectations (e.g. façade arrangement) - from indoor to outdoor view – in generally it prescribes that the building should have an open outwards directed appearance. Also it relates to healthiness and daylight.
2	Identify the social and cultural, natural, personal circumstances considered from the different perspectives: Societal ➢ The aesthetic value/proudness and experiences, identity, transparency; appearance in school design, belongingness to the community/neighbourhood; view experiences of indoor school activities Users: ➢ - psychological need for safety and security ➢ - physiological experience of outdoor activities, outdoor views on greenery, and avoidance of outdoor traffic noises; - bio-physical need for daylight, a shelter for weather circumstances, and experience the natural differences in sunlight/daylight/seasons intensity.
3	Identify the human needs related determinants: Societal ➢ Feeling connected (appearance inwards/outwards), significance (architectural design, local identity, local pride), feelings of growth/contribution (education) Users: ➢ Feeling certain (shelter for weather conditions), feeling variety (changing weather conditions, season changes)
4	Identify the positive side-effects of both perspectives: Societal: ➢ Large window frames reinforce the built form and activates the life of the street, that give passersby an opportunity to glimpse the life inside. The transparent architecture provides vistas for pedestrians as it does for occupants. Large windows generate passive solar energy. Users: ➢ Large window frames reinforce the psychological effects of shelter, and physiological effects of sight on greenery, and nature experiences (variety in weather conditions, daytime and seasons, healthiness). Open a window frame gives fresh air flow experiences.
5	Identify the negative side-effects: Societal: ➢ Current architectural design might be experienced as cold, unattractive and not supporting local amenity or feeling connected to the school. Large window frames also generate energy loses (e.g. Nord-side). Users: ➢ Large window frames might cause more traffic noise, sunlight hindrance/reflections and overheating. Postmodern architecture using relative low ceilings generates small fresh air buffers. Opening of the windows frames might give pollution or fine dust in cities, and allergies in the certain seasons. Large windows cause easily distracted pupils.

In this example an end-user perspective of a window frame mainly covers the need for certainty factors (e.g. sheltering for bad weather conditions, sight on greenery), and somehow the need for variety, satisfied by the constant changing outdoor activities (e.g. changing weather conditions, and sight on pedestrians). From a societal perspective it mainly covers the need for social connection and significance by exhibit a certain typology of school design whether or not is appropriate to the social communities pride.

3.2.2.2. Separating the individual needs of the heterogeneous end-user needs

Arise in number of pupils with special educational needs is identified by the Dutch Central Office for Statistics (CBS 2015). This rise is also identified in other west-European countries. An increasing number of children with special educational needs stay at home without following any education. The term special educational needs covers children who have learning difficulties, for example, autism spectrum disorders and attention disorders. Recently published work states, that one of the four children is labelled with such a disorder (Weghorst 2015). This increases the demand for PLEs. Individuals differ by:

1. Bio-physical differences (e.g. age and gender, impairments, disorders and characteristics);
2. Physiological differences (e.g. visual, auditory or kinaesthetic preferences);
3. Psychological differences (e.g. cognition, motivation, autonomy, competence, social connection and learning styles variations).

3.2.2.3. Four polarity characteristics in a heteronomous–heterogeneous perspective

Within the four elaborated principles, four polarity directions are considered to be a main guidance to simplify the heteronomous–heterogeneous physical learning environment relationships. Taken into account these four elaborated principles, as human needs related characteristics, these polarities are used to consider the end-user needs (in particularly the need for certainty and variety as known from the child development psychology) interests from a societal perspective by:

(1.1) downwards directed needs for certainty, for example, the strive for societal connection preferences working with the 'laws of nature', such as biophilic design. From this perspective end-user need for certainty are, for example, fulfilled by feeling secure and safe in the learning environment;

(1.2) outwards directed heteronomous needs for certainty, social connection and contribution. For example, the strive for societal interests, such as shown by social design and collective design (e.g. Hocking, Brown, and Harris 2016); From this perspective end-user needs are fulfilled, for example, by the need for certainty such as by working in a group setting instead or working solely;

(1.3) inwards directed autonomous need for variety, significance and growth. For example, the strive for societal growing attention for PLEs; From this perspective end-user needs are balanced by, for example, stimulating identity, curiosity, creativity and challenges;

(1.4) upwards directed need for growth, for example, the societal technological developments, such as the strive for E-learning, and interaction design (e.g. Hartson 2003), or by means of using devices, wearables and so on to control the environment collectively. From this perspective end-user needs are fulfilled by, for example, a challenging variable technological learning environment (e.g. virtual reality).

Referring to the four principles, the separation of societal and end-user needs, and the choice for a simplified method which uses only these four polarity approaches, a balance might become feasible within end-user needs for certainty and variety from a societal perspective of all six needs.

3.2.2.4. Three personal characteristics in an autonomous-personal perspective

Three specific characteristics are considered as a main guidance to simplify the autonomous-personal physical learning environments relationships of control. Taken into account the four principles these three interrelated characteristics are used to consider the end-user interests from an individual perspective, subdivided by end-users' control of time, arousal and place factors. Noticed is that end-users are mainly pupils in this paragraph, but also teachers and pedagogues are involved (with other needs patterns).

(2.1) the time impact factors content: pupils' control of well-being by bio-physical aspects (e.g. ergonomic such as long-time sitting on the chair); physiological (e.g. chronic noise exposure) and psychological factors (e.g. long-time working solely). The principle of the temporarily impacts, suggests also the presence of a feedback mechanism between the environmental objective situational factors and individual end-user (optimal) activation level. For example, the relations between alterations of functions over time and users' behaviour, such as described by Altomonte, Rutherford, and Wilson (2014). Another level of time-related example is pupils development and their physical learning environment shift of interests relationship. A shift in accent from the need for certainty (young children) to the need for variety (older children) during their school time period obviously relates to the need for variation in school-building design interior experiences. Thomas Hobbes (1588–1679) described in his book 'Leviathan' (1651) the philosophical theorem that a cyclical period of human satisfaction always is followed by a period of human fight, to strive subsequently for well-being again, until the state of wellbeing of restored comfort is decreasing again. Butter (1997) assumes that there might be no simple one to-one relationship between needs and satisfiers (Butter 1997). Except that there are many possible satisfiers for any need, there are also factors that provide multiple needs satisfaction simultaneously (Butter 1997). Butter states that a requirement of one category may be postponed in favour of gratification of another class, or of another person (Butter1997). The feelings of fulfilment cannot be stored and always slowly begins to fadeaway which might cause unbalances in needs fulfilments. Psychological, physiological and biophysical personal conditioning experiences and evolutionary based experiences also illustrates the temporarily fulfilment of human needs (Heerwagen 2003): "*Natural light changes significantly over the course of the day, providing a signal of time that was crucial to survival throughout human history. Being in a safe place when the sun was setting was not a trivial matter for our ancestors, and it is still important to human well-being*" (Heerwagen 2003).

Not all needs will or have to be satisfied by school activities and physical experiences only, because the satisfaction of needs can be postponed. For example, by outdoor or at home activities: 'Place related the needs are fulfilled at home, outdoor activities, sports etc.' (Heerwagen 2003), or socially instead of physically experiences. Also in these approach should be noticed that in time the paradox effects might have less impact due to habituation. This principle illustrates the importance of fulfilling the need for variety by means of the changeable challenging learning environments which should although remain in balance with a structured learning environment as fulfilment of the need for certainty.

(2.2) the arousal factor: pupils control of balancing autonomously the physical learning environment conditions, and optimizing the personal activation level by balancing the physiological conditions such as the sensory experiences of temperature, heating, and air quality (Earthman 2004). Oseland and Hodgeman (2015) state: "*Psychologists generally agree that different personality types have different innate levels of arousal, which in turn affects how noise has an impact on their performance. People can perform better if they are stimulated or motivated (which increases their level of arousal), but there is a limit because too much stimulation can lead to stress and thus reduce performance*" (Oseland and Hodgeman 2015).
Another arousal-related example is illustrated by pupils with special educational needs, who overload themselves by too much stimuli at school and discharge totally at home. Bell et al. (2001) describe a general eclectic-environment-behaviour model to residential and institutional environments, within which the relationship of arousal and activation levels of percept design, and in case of when inadequate for user needs it causes stress, overload and/or reactance (Bell et al. 2001).

(2.3) the place factor: pupils' individual control of balancing their needs by change of place, such as searching for a place to feel themselves at home. The learning environment and the occupants are considered as a continuum, as one construct. Also personal needed space might be considered as a place related factor individual influenced by personal control. Another place-related example, which states the personal characteristics as need for autonomy, is illustrated by bio-physical differences, such as gender and age differences, which are significant enough to take seriously in the physical learning environments (Schellen 2012). This states also that boys in classrooms need different conditions, such as room temperature, than their female peers by gender differences, or in case of female teachers by their age differences.

Considering the six human needs related four principles, in particularly the four polarities and three personal characteristics, a separation of multi-level scaled stakeholders is considered to articulate their specific interests. Figure 3.4. illustrates how the four polarities of balancing human needs directions are balancing inwards and outwards directed, and upwards and downwards directed. It also shows the relationship of the interrelated personal factors, within which the three autonomous-personal controllable characteristics of time, arousal and place, relates to the other principles, such as the interrelationship of psychological, physiological and bio-physical domains. This model illustrates the polarities and individual characteristics as well as these three domains, with which should be noted that this mechanism works also, as further articulation of the social fractal, for societal and institutional stakeholders interests (see Figure 3.4.).

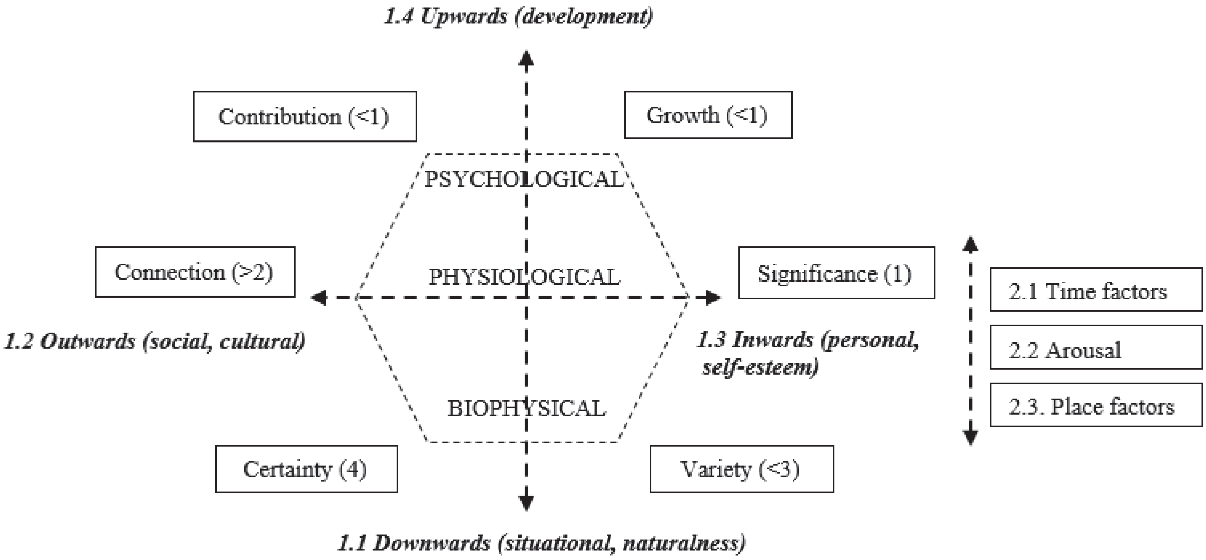

Figure 3.4. The social fractal of dynamic human needs polarity mechanism.

3.3. Results

The established principles offer a theoretical analysis as a new perspective to define the design quality indicators, and to offer a main guidance by the NCGs for primary schools. The four principles form together with the step plan of considered continuums, seven main characteristics (four general polarities and three specific individual characteristics) to define the physical learning environmental shells fit to end-user needs. The seven main characteristics together enable more adjustments within the personal preferences. To elaborate the heterogeneous end-user design indicators, the performance (P) is, in terms of well-being, health and behaviour, defined by the product of (six) Needs (N), (six) Shells (S) and the (seven) Characteristics (C):

$$P = (6)N \times (6)S \times (7)C$$

A matrix (see Tables 3 and 4) illustrates the six human needs relationships and the six physical shells (and within it the seven characteristics). A generic simplified approach has been pursued by considering the four principles and continuums of heterogeneous group (step 1), individual end-users (step 2), their heteronomous relationship with the physical environment using four polarities (step 3), and the autonomous relationship influencing the polarities using three specific individual characteristics (step 4).

3.3.1. The matrix

In order to determine the end-user indicators (continuum 3) and individual characteristics (continuum 4) a matrix is elaborated to frame the needs and physical shell relationship. The matrix shows 36 cells to determine the end-user indicators. It also can be useful to determine other stakeholders indicators' perspectives, and to balance them together by the different interests (the architectural synthesis), but in this approach it states the theoretical analysis based requirements. The bold numbers mark two illustrative examples for child development psychology based need for certainty and variety (see Tables 3.3. and 3.4.).

Table 3.3. Coded number of the matrix of human needs for certainty and physical learning environment relationship.

	Human needs for certainty downward (and outwards directed)					
Physical shells	**Certainty**	Variety	Connection	Significance	Contribution	Growth
Desks	**1c**	1v	1sc	1s	1co	1g
(Class)rooms	2c	2v	2sc	2s	2co	2g
Corridors	3c	3v	3sc	3s	3co	3g
Exterior	4c	4v	4sc	4s	4co	4g
Playground	5c	5v	5sc	5s	5co	5g
Neighbourhood	6c	6v	5sc	6s	5co	6g

Table 3.4. Coded numbers of the matrix of human needs for variety and physical learning environment relationship with personal characteristics.

	Human needs for variety downwards (and inwards directed)					
Physical shells	Certainty	**Variety**	Connection	Significance	Contribution	Growth
Desks	1c	1v	1sc	1s	1co	1g
(Class)rooms	2c	2v	2sc	2s	2co	2g
Corridors	3c	3v	3sc	3s	3co	3g
Exterior	4c	4v	4sc	4s	4co	4g
Playground	5c	5v	5sc	5s	5co	5g
Neighbourhood	6c	6v	5sc	6s	5co	6g

These bold cells (1C and 2V) are considered within their principle based characteristics. For example, the end-user physical shell position considered from, in the first example 1C, a learners-desk relationship with the need for certainty, is also influenced by the outwards directed polarity characteristic. That is why the table colours dark for the main down-wards directed need for certainty, and light for the impacts by the outwards directed polarity. The other example of classroom and the need for variety is also downwards directed, but here more inward directed. Because of the relationship with the personal characteristics, also the autonomous end-user individual needs factors are involved.

The heterogeneous end-user group needs demand a heteronomous approach of interaction to control the learning environment, using the four polarities as main approach [1.1–1.4]. The personal end-user needs demands an autonomous approach of interaction to control the learning environment individually by using three characteristics [2.1–2.3]. The two examples illustrate the heteronomous and autonomous relationship and opportunities to determine the technological building abilities to control the physical learning environments. It also illustrates the dualistic, but still coherence, approach of certainty and variety and so on relationships to balance. The two illustrative examples are elaborated from an end-user perspective (teacher perspective on pupils). The analytic results are compared with educationalists perspectives by a number of interviews in 2014.

Hence, the interview phrases are coupled afterwards to the theoretical analysis that are illustrative for the development of the design quality indicators. The interviews were conducted in 2014 (Kars 2014), and the transcribed data of educational perspectives are compared with the theoretical approach, which prove a lot of similarities. The interviewed teachers, which phrases are shortened, worked on the existing schools during that period. The schools are selected by different building years (see Table 3.5.).

Table 3.5. Overview expert interviews of educationalists perspectives.

Interview	Sort	Type of education	Place (NL)	Year built
Teacher 1:	Primary School	Public School	Harkema	2008
Teacher 2:	Primary School	Public School	Leeuwarden	abt. 1920
Teacher 3:	Primary School	Christian Dalton	Leeuwarden	abt. 1960
Teacher 4:	Primary School	Public School	Dokkum	abt. 1980

The main questions were focused on Personification (needs for personification); Inclusive education (where do you recognize the special needs?) and Technology (will there be a change in the learning environment by the technologization?). Two illustrative examples are elaborated from the stated theoretical approach and from educationalists perspectives from an end-user perspective. The theoretical approach descriptions illustrate the model-based design quality indicators (see Tables 3.6. and 3.7.).

Table 3.6. Example code: 1c theoretical approach and educationalists perspectives.

<table>
<tr><th colspan="2">Code: 1c – physical shell pupils' desks workplace analysed by the need for certainty (downwards and outwards directed)</th></tr>
<tr><td colspan="2">Heteronomous end-user group interaction factors</td></tr>
<tr><td>1.1.</td><td>THEORETICAL APPROACH
Situational and naturalness factors: the polarity is downward related which emphasizes to use a variety of natural materials e.g. wood, stone, loam, et cetera; The need for certainty emphasizes that every learners desk place should be related to natural biophysical experiences (natural colours, natural sound and acoustic levels, natural heating e.g. by solar radiation); artificial, synthetic materials and toxics should be avoid as much; strive for a natural learning environment for learning (e.g. embodied learning, ergonomic comfort, combine bodily with cognitive activities); bodily needs, such as natural environments for essential exercises (e.g. use of stairs) should be taken into account in the layout of the design.

EDUCATIONALISTS PERSPECTIVES
T1: a lot of pupil prefer to sit near the large windows. Why? I think to experience daylight;
T1: what I often see what is going wrong is the indoor air quality…and also moisture, carbon dioxide emission, and temperature, that should be controlled better..…for all the pupils;
T1: children have an own box in their desks for the general books and an own drawer in the desk for private stuff…so they are flexible to walk to, for example, a higher grade group and taken with them their own drawer;
T1:if children with an disorder have a separate place, they show no disturbing behaviour for others;
T3: children like to be protected entirely and to see nothing of the surroundings…sometimes it is enough to see nothing which makes noises less important for them;
T3: we do have a silence place to work (where it is not allowed to speak) with no stimuli…we also have a kind of hutch at the back in the classroom, in fact a shielded desk;
T3: what is missing is a time-out room when you need it, as a teacher for just a moment…or for the children;
T3: some pupils want to sit at the front because they cannot see well…especially due to the daylight hindrance on the digital screen;</td></tr>
</table>

	T3: I don't think it is ergonomic right to let children of all ages work at the same chair and desk heights; T3: there should be workplaces outside the classroom; T4: perhaps a classroom should be a hexagon instead of a square to create overview.
1.2.	THEORETICAL APPROACH Social and cultural factors: the polarity is outwards directed, which emphasizes the use of a group setting of desks. The need for certainty emphasizes to fulfil the need to feel safe by the desk positions into the classroom. These feelings might be enforced by using removable cabinets or panel-walls to create corners and position them around or behind a group of pupils as a shelter; creating an stable structure of desks settings; enhances the feelings of safety in (class)room arrangement; it is desirable to design different places/corners in the (class)room to change the desks arrangement settings regularly but predictable by using structure; the desk positions should improve social interactions; EDUCATIONALISTS PERSPECTIVES T1:sitting at the rear of the classroom is favourite, as a hidden place, or behind a group of pupils that not see you but only see them, some pupils like to sit at the front of me and find it very enjoyable; T1: there should be standard regulation to mute the sound and dim the light to create sphere in parts of the classroom where pupils work in groups; T1:I think about low quickly to move separation screens and easy to arrange corners, just for better performing plus-pupils; T2 I think that digitalising the classroom leads increasingly to less working on a desk….you also can work on a couch with your tablet…than you can create a total different sphere in a school…. T4: it is sometimes very hard to deal with children with a disorder…I also have to deal with children without a 'label' such as one who cannot behave himself when he is alone …or one who cannot speak well and always starts fighting when he is plagued;

Table 3.7. Example Code: 2v theoretical approach and educationalists perspectives.

Code: 2v – physical shell classroom analysed by the need for variety (downwards and inwards directed)	
Heteronomous end-user (pupils) group needs factors.	
1.1	THEORETICAL APPROACH Situational and naturalness factors: the polarity is downward related which emphasizes to use a variety of natural materials e.g. wood, stone, loam, et cetera.; the need for variety emphasizes also the use alternating season related experiences for biophysical bodily processes relationships. It also relates to physiological needs, such as the use of a variety of different nature related spaces and forms, and natural colours, sounds and acoustic levels; natural resources implicate that passive solar energy should be stimulated while unnatural heating should be reduced. Artificial synthetic materials and toxics should be banned; a strive for conformance with pupils' natural way of learnings e.g. embodied learning is preferred; the use of stairs to stimulate exercises, and the use of different routes (without disturbing activities elsewhere) should be stimulated in designs; preferred is a design by natural environments with surprises and challenges to stimulate pupils' creativity. EDUCATIONALISTS PERSPECTIVES T1: new kinds of education make the principle of classroom rather vague, when you get flexible rooms, so must be also the air-tubes and so on; T1: we do not talk about classrooms but about workspaces for children, such as our learning square; T2: you should have a building where you can create different corners to organize a variety of learn tasks, and realize some rest what is important; T2: if the space can be arrange differently, we are be able to teach the children differently; T2: that you can make one big room and subsequently turn it to two or three rooms…that you should not think in classrooms but in open rooms that you can close and open in a certain way;

	T3: control of the indoor temperature is not possible well…when it is too hot children become musty…and when I open the windows in the winter period it leads to unwanted cold air flow; T3: a lot of daylight is fine, but too low positioned windows give too much outdoor stimuli; T4: perhaps a classroom should be a hexagon instead of a square to create overview.
1.3.	THEORETICAL APPROACH Personal and self-esteem related factors: the polarity is inwards directed which emphasizes a variety of special rooms for all kinds of activities; the need for variety emphasizes also the use different room sizes, forms and sensory experiences in the (groups)rooms; the use of different colours for different rooms, and different acoustic/noise levels, different sunlight/daylight experiences and temperatures in the rooms should be part of the design brief; the design layout should have different places/spaces, indoor and outdoor, to challenge pupils personal self-esteem and identity. EDUCATIONALISTS PERSPECTIVES T1:a child cannot develop itself without classroom adjustments; T1: at Christmas time another sphere is realized by the lights in the tree…I wonder why we do not do this more often in other circumstances, such as when we are reading books… T2: children need variety, such as for embodied learning and serious gaming…in a small classroom this is not possible to execute; T2: it would be great when you have a podium or a place to put a child once in the spotlight; T2: we do not have a room where pupil can collaborate for those who has the ability to perform on a higher level….everyone has to be quiet in current classroom situation; T3: our aim is to make children owner of the rooms…for example, the responsibility of the library is designated to two of our pupils…;
Autonomous end-user (pupils) individual needs factors (inwards directed)	
2.1.	THEORETICAL APPROACH Time factor: to fulfil the need for variety individually, the physical learning environment should be changed autonomously easily, as well as temporarily by size and form; the use of autonomous changeable indoor walls or changeable classroom arrangement setting can regulate and stimulate the sensory experiences and activation levels for individual needs. EDUCATIONALISTS PERSPECTIVES T1: I thought about how easy it should be to turn tables plateaus, to isolate themselves, and to start a new task by turning to the group at the time when needed; T2: I want to work at a place for children where they can work independent from classroom times, such as that they can work into the classroom but also elsewhere, at different moments; the role of teachers should be more like a coach and interact with pupils' needs;
2.2.	THEORETICAL APPROACH Arousal factor: to fulfil the need for variety individually, the physical learning environment should be changed autonomously easily, as well as its arousal level; stimulate the sensory stimuli by personal preferences (e.g. variation in the personal preference of control the ventilation, thermal comfort, natural light, noise and privacy); use technological controlled devices in classrooms to control individual needs. EDUCATIONALISTS PERSPECTIVES

	T1: much colours soon will be too much…especially for children with a disorder it will give too much arousal; T1: there are differences in stimuli levels, but also in changing the instruction places and moments; T2: children sitting near a door or a window should not have hinder experiences; T2: you don't have to control individually everything…but sometimes the teacher needs a higher classroom temperature while the classroom is sweltering…it would be ideal that the child should control its own temperature and ventilation… T2: I can imagine that there is a difference between boys and girls, because boys are often more motile…those boys are often getting warm by their movements, and girls don't.
2.3.	THEORETICAL APPROACH Place factor: to fulfil the need for variety individually, the physical learning environment should be changed autonomously easily by change the indoor walls, vary the levels of (day)light, temperature, colour, sound and so on; the ability to change the classrooms into other educational functions increases the building usability; create more flexibility and open classrooms into the building for individual needs. EDUCATIONALISTS PERSPECTIVES T1: it would be nice when there are four corners with different colours, and to distinguish the children by their differentiations…but it is not possible in practise to paint all these different colours; T1: it is not good to separate the children from the group always.….it might be better that a child can isolate itself when needed, although, the teacher should also steer this; T1: a child with ADHD and also ASS should choose their own furniture or corner where to work in or outside the classroom; T1:a child with an ASS disorder can be best placed in the back of the classroom to create overview, and should not be placed close to a window or door; T2: then you notice that the physical classrooms are too small for groups of 30-33 children when everyone touches each other, which creates a too crowd situation for pupils with a disorder;…if groups are getting bigger, than the number of children with disabilities also grows; T2: the corridor is not a place for those children, there is no silence; T2: to use the talents of inclusive education, especially different learning environments are needed; T2: we have many ideas how to do it differently, but we don't have the room for it; T3: children can be very angry…we like to have a time-out room with such a kick-fun sack to let off steam; T4: you should have several corners in the classroom for children with Asperger…you are so constrained by current classrooms; T4: the more children in the classroom, the more it disturbs them, such as children with Asperger syndrome (ASS) dislike noise and crowd…they become totally upset when they come at home after the school period.

3.3.2. The guidelines

Considered are the six human needs and the six determined physical learning environmental shells, within which the complexity is reduced to five guidelines as manageable steps (see table 3.8.).

Table 3.8. Needs-centred guidelines.

1	Consider the scope of the four principles of human needs relationships: (1) physical environmental shells; (2) end-users' psychological, physiological and biophysical interests; (3) the dynamic mechanism and ratio balance and (4) the needs paradoxes.
2	Separate the end-user's needs from the societal needs within the [1st] continuum. Be aware of their different perspectives and possible conflicts with other interests (e.g. institutional or process actors) within this continuum.
3	Separate the individual's needs from the end-user's needs within the [2nd] continuum. Be aware of different individual perspectives and possible conflicts with someone else's perspectives and with other end-user interests. For example, different end-user interests could be caused by gender and age differences and different personal characteristics.
4	Relate end-users' heteronomous interests to the adjusted heterogeneous physical learning environment within the [3rd] continuum. Be aware of the societal interests influencing end-users as well as building performances. Use the four-polarity balance as a central point of approach to define the physical learning environmental shells within the paradoxical relationship pattern of down- and upward and in- and outwards-directed human needs, whilst considering the biophysical, physiological and psychological time-related influences.
5	Relate individual end-users' autonomous interests to the adjusted personal physical learning environment within the [4th] continuum. Be aware of personal interests influencing end-users as well as building performances. Use the three personal characteristics of time, sensory stimulation and place as a specific approach that define the individual to adjust to physical learning environmental shells, within the paradoxical relationship pattern of down- and upward and in- and outwards-directed human needs.

3.3.3. Tested model

We related the theoretical approach to the educational perspectives and established the guidelines. Yet a small illustrative example shows how the model works in practical application of the process and can be used particularly for primary school design. The by Gaudí's constructed Parish Schools of Sagrada Familia near the site of the Basilica and Expiatory Church of the Sagrada Familia is examined by the guidelines. The book Gaudí's Sagrada Familia (Anglés 2010) is used and recognized are, by the short phrases in the book, the model adjusted similarities. Gaudí carefully designed all the details of this school, trying to make it as pleasing for the children as he could. Noted is that the Table 3.9 is from an end-user perspective. Hence more balance can be found in practical application when also the societal interests are known, as well as the more detailed personal needs of children with disabilities. Hence, the guidelines 3 and 5, which assess the personal requirements, are not used in this example. Using the guidelines in practical applications of the process, a distinction between the three approaches by societal, end-users (example above), and individual interests improves the awareness to balance the different interests (see Table 3.9.).

Table 3.9. Example tested model Gaudi's Parish Schools of Sagrada Familia.

NCGs from an end-user perspective			
7 Characteristics	**6 Human needs (and impact)**	**6 Physical shells**	**Phrases from the book :**
Biophysical			
1.1 Downwards (Situational, Naturalness)	**Certainty (4)** related to variety	Desks/furniture	The stools for giving classes in the open were three legged so that they would remain steady on the ground. A practical four-sided gyratory cupboard where the class material was kept. The arrangement setting was two by two.
		(Class)room	The classrooms were built to occupy at least 50 children. The roof (in this case conoids) consists of a very simple structure, visible from inside the three classrooms (that helps to understand the generation of the ruled surface).
		Corridor/room relationship	There was only a small hall/entrance.
		Exterior/lay-out	Ruled surfaces (planoids or false planes) in the walls and roof are used; forms frequently found in nature.
		Playground	Teaching in open air. An area covered with heather extended over a metallic grille, where plastered walls doubled as blackboards.
		Neighbourhood	Gaudí built the school near the church for the sons and daughters of the workers at the church and the local children
	Variety (< 3) related to certainty	Desks/furniture	The classroom differ in arrangements settings and in classroom arrangement settings, by blocks of 48 desks and some separate desks also two by two (which suggests that they might be used for some individual pupils.
		Room	All classrooms had different sizes, and no classroom was the same, and had straight and curved walls.
		Corridor/room relationship	The toilets were located on the opposite of the entrance.
		Exterior/lay-out	The geometry of conoidal surfaces so abundant in nature The conoidal brick walls that enclose the construction are generated by straight lines which follow the initial sinusoid floor plan and which result is pleasing to the eye extraordinarily stable and naturalistic at the same time.
		Playground	At the other end of the patio (besides the area covered for blackboards) there were trees and jardinières with plants that the children grew, meant to instil them the love and respect for nature.
		Neighbourhood	The organic design variation for the traditional architecture styles and typology.
Physiological			
1.2 Outwards (Social, cultural)	**Connection (> 2)** and related to certainty and contribution	Desks/furniture	An arrangement setting of two by two
		Room	The classrooms had a huge air volume due to the high ceiling/roof. Small window frames did not disturbed the children by outdoor occurrences and create less sun radiation/overheating. Cross ventilation was possible by the tilt windows.
		Corridor/room relationship	The entrance to enter the classrooms was located in the centre of the building.
		Exterior/lay-out	On the ground floor there are three intertwined hearts, probably meant as symbol for the Christian religion.
		Playground	In one of the playground there was a round pond 30cm deep that was used for practical classis of Geography, where pupils

			had fun using sand to reproduce the geographical incidents they had studied.
		Neighbourhood	The school is inseparably connected to the natural architecture and meant to collaborate in the education of the quarter's children and adults.
1.3 Inwards (Personal, self-esteem, Individualisation)	**Significance (1)** related to variety and growth	Desks/furniture	The pictures in the book show that some learners desks are situated separately.
		Room	The pictures and layout show that no classroom is equal.
		Corridor/room relationship	Every classroom has separate toilets.
		Exterior/lay-out	Around the building Gaudí built 'jardiniéres' with rough rocks, where each child had a plant assigned in order to awaken in him love and curiosity for nature.
		Playground	The pupils took care of the plants assigned to them in the jardinières around the building. In one of the playground there was a round pond 30cm deep that was used for practical classis of Geography, where individual pupils in the centre of the peer-group in turn (as pictures show) reproduced the geographical incidents they had studied.
		Neighbourhood	The organic design was new and very significant in relationship with other buildings.
Psychological			
1.4 Upwards (Development)	**Contribution (< 1)** related to growth	Desks/furniture	Organic design characteristics
		Room	Organic design characteristics
		Corridor/room relationship	Organic design characteristics
		Exterior/lay-out	Organic design characteristics
		Playground	Playground relates directly to their classrooms
		Neighbourhood	Organic design characteristics
	Growth (< 1) related to contribution	Desks/furniture	Organic design characteristics
		Room	Growth might be experienced within the rooms, and playgrounds (e.g. the height of fountain)
		Corridor/room relationship	Organic design characteristics
		Exterior/lay-out	Organic design characteristics
		Playground	The geographical pond in just one of the playgrounds ; Gardening lessons to rouse the interest, respect and love for nature in the children.
		Neighbourhood	Organic design characteristics

3.4. Discussion

We noted that current design indicators are largely influenced by societal and institutional interests, which neglect some essential pupils' psychological aspects, such as pupils' core need for variety, creativity, fantasy and challenges in the school design environment. We assume that more awareness of the underlying pattern of human needs contributes to a better understanding of the balance between the physical learning environment from human needs perspectives fulfilled socially and physically, and alternating. This approach might tackle the current complexity of interwoven interests and in particular it avoids excessive complexity for traditional design and management teams, for example, by using Network sciences. The simplified principles are elaborated to contribute to the essence of the guidelines. For example, they can be considered in a broad continuum of multi-level stakeholders, due to their base in the so called social fractal pattern. We argue that a systems thinking approach might contribute best to the discourse of balancing all different perspectives and needs, to achieve a well-fitted learning environment. We also notice that not all interests might be conflicting, but that this should be examined in the design process dialogues.

This method relates to universal basic needs theories, the child development psychology and environmental psychology-based approaches. Many studies state that a well-fitted learning environment will never be reached with univocal results within the complexity of subjective end-user needs. From this point of view, we argue that a separation of social (e.g. peers, teachers) and physical (e.g. material, colours, forms) environment interactions is undesired, because of their interactions and substitutional alternating interventions. For example, when a child is afraid by a social event in the (class)room, the child will wants to hide in the physical environment, such as into a corner, to find security. It should be noted that social impacts always have more influence on end-user performances than physical environments. The fulfilment of needs takes place emotionally, by both, social and physical experiences, psychologically, physiologically and biophysically. We assume that this is far more important to focus on than to a distinction of which physical and social aspects really matters.

The understanding of underlying patterns offers a rather simplified method to manage the complexity of the design quality indicators or key performance indicators, as illustrated by the examples from an end-user perspective. The polarities should not be approached too literally, because we should not forget that these are just words which express certain feelings. With the new guidelines we assume to offer a reasonable alternative that gives new insights into the complexity of end-user needs and the physical learning environments. This approach might also stimulate future directed opportunities for intelligent algorithm-based building control and might contribute to more balanced client briefs. Although it is still a hypothetical proof of concept, we argue there is ground for this fundamental but simplified approach.

3.5. Conclusion

Our aim was to develop guidelines that are based on a full assessment of human needs by means of a theoretical analysis to enable more balance in the architectural synthesis of societal, end-users and individual interests. We elaborated a recipe that generates the NCGs for primary schools in particularly to provide a better balance between societal and individual end-user needs. In this article, human needs related principles and a step-plan method are elaborated to achieve more balance within the continuum of societal and end-users' interwoven relationships. The method also generates detailed design quality indicators to define the physical subjectively experienced learning environmental shells, and to meet end-user needs, generously and individually. This new integrated approach implicitly offers new insights to adapt technological innovations that contribute to end-users' heteronomous and autonomous control of their learning environment by understanding the underlying pattern of human needs. We argue that defining sustainable, healthy and innovative school buildings should start explicitly with generating more awareness of end-user subjective psychological and physiological basic needs. We argue also that technological adjustments contribute integrated via this pathway end-users' objective bio-physical interests. The results are still hypothetical and a concept of proof. In forthcoming research, the related sustainability guidelines for defining the objective school building physical learning shells will be elaborated.

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Chapter 4
ENVIRONMENTAL INTERESTS

An analytical approach towards sustainability-centered guidelines for Dutch primary school building design

ABSTRACT

Societal one-way directed approaches of sustainable primary school building design cause persistent physical building problems. It affects the performances of the societal challenge of designing real sustainable school buildings, as well as the educational and social processes, and its end-user performances. Conventional building construction approaches build traditionally their designs on a syntheses of dialogues and consensus during decision-making processes, due to a variety of different interests. Principals define their ambitions and requirements into a team of mainly technical domain related disciplines. There are no design methods available that connect human systems and ecosystems integrated and balance the dynamic multi-level scaled mechanisms of human needs and sustainability development factors. The presented analytic framework recognizes similarity patterns between these multi-level scaled social systems, ecosystems and sustainable development entities, qualitatively as well as quantitatively. It delivers a new polarity based dynamic system that contributes to the client briefs and physical building morphological factors from a more sustainable development base. This theoretical approach establishes Sustainability-Centered Guidelines for primary schools (SCGs) design and building.

Keywords: architectural design process; sustainable design; sustainability; school buildings; indoor environment

Additional information chapter 3	
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[a] Hanze University of Applied Sciences – Research Centre for Built Environment NoorderRuimte, Van Doornveste, Zernikelaan 11, 9747 AS Groningen, The Netherlands.
[b] University of Groningen - ESRIG Energy and Sustainability Research Institute Groningen, Centre for Energy and Environmental Sciences, Energy Academy Building, Nijenborgh 6, 9747 AG Groningen, The Netherlands.

4.1. Introduction

The Dutch governmental agency for business affairs RVO states 17 persistent problems in primary school design [1]. A complex interwoven diversity of multi-level scaled interrelated physical building and process related problems are involved due to a variety of interests, such as between governments, municipalities, school management boards and educational advisors, local communities, and end-user needs, and between these various stakeholders and related construction companies. The persistent failures of existing practices during the process and during the whole life cycle of the building describe a complexity that relates especially to the school building design process. For example, bad collaborations, inexperienced principals, complexity of responsibilities, distrust, a fragmented supply market, split incentives, finance systems, political underspending policy, and the role of the demand side et cetera [1]. It might be no wonder that this process generates also problems relating to the building performance, such as a bad indoor climate quality and a dissatisfied sustainability and energy performance, and subsequently the different interests make it even more worse. For example, the end-users need a good indoor quality and functionality of the physical learning environment, but political ambitions of maintaining the regulatory of good housing are mainly focused on the social process of good education. At the end they do not advocate to balance with end-user needs. A variety of these complex interwoven failures of existing practices starts with, for example, the different governmental ministerial responsibilities. For example, one ministry increases the building legislation rules to improve the sustainability goal, and another ministry shortens the financial budgets limiting good operation and maintenance [1]. The Dutch national government presents it as that it is hard to establish sustainable buildings due to all different definitions of sustainability, which makes it hard to make proper arrangements between investors, principals, constructors, and end-users [2]. Also a fast changing world of technological, economic, sociological and political changes makes it also hard to anticipate on future changes and educational trends see [3, 4, 5, 6, 24]. Dahl states that it is urgent to find better systems of progress towards sustainability and referred to the high dynamics of technological progress and globalization accelerating change in many economic, social and environmental processes [7]. These changes and effects emphasize the need for on the one hand a specified definition for sustainability, such as has been done by optimizing the sustainability ambitions of building construction and its performance and the use of sustainability assessment tools (e.g. BREEAM), and on the other hand to anticipate future changes, such as done by emphasizing a more holistic integrative perspective of building functionality by more flexibility. But the difficulties of the interwoven multi-level scaled complexity of physical primary school building performance problems, challenge also the politics to enhance more sustainability, not from only a definition, but also from incorporated sustainable development objectives in performance building regulations. For example, the challenge, such as stated by Koskela, an interdisciplinary discussion on the theory of the build environment recognizes as an artefact, as a process, and as an ecosystem [8]. To improve the indoor climate quality of learning environments it is needed to consider all causes and effects from different levels of scales in an integrative way. For example, Grün & Urlaub state how improvement of the indoor environment on learning in schools in Europe can stimulate economic growth [9]. Obviously there is a relationship between the bodily effects of the end-user as environmental effect, and the huge economic effects between different sustainable development scales, such as healthiness and welfare.

The Dutch education system is one of the best systems in the world, and recently the ranking is moved from ‘good’ to ‘great’, referring to the report “Netherland 2016 foundations for the future” [10]. Whilst the educational system is great, the physical learning environments remain worse, for example, such as caused by the poor indoor climate quality of the primary school buildings [11]. The UNICEF report “child well-being in rich countries” states that the Netherlands is the clear leader in material well-being, health and safety, education, behavior, and, housing and environment [12]. Hence, remarkable antagonistic perspectives are identifiable between social systems (e.g. a good education system), and ecosystems (e.g. bad indoor quality). It should be noticed that Dutch children spend 90% of their time into buildings. Although the Netherlands is socially doing well for children, the high social education standard, well-being, and economic welfare obviously has hidden environmental costs. For example, the lack of integrative approaches is also stated by the worse quality of Dutch biodiversity, which is the worst of European countries by its reduction of 15% of its origin in 1900, due to intensive agriculture and urbanization factors influences [13]. To state the unbalanced situation from a multi-level scaled perspective of primary school building relationship with sustainable development, even more remarkable is the by United Nations University presented World Risk Report that reports a research of 171 countries in the world, within which the Netherlands ranks as most dangerous country in Europe, due to its high sea-level and low land-level risks [14].

Life Cycle Assessments (LCAs) are the instruments to measure levels of the environmental performance, also often used for buildings. Life Cycle Assessments (LCAs) are widely used, for example, in manufacturing industry, and generate metrics of environmental impacts and waste streams. LCAs can be classified in three levels, such as product comparison tools (e.g. Simapro), whole-building design tools (e.g. Ecoquantum), and whole-building assessment systems (e.g. BREEAM), see [60]. Besides BREEAM, the Dutch assessment tool GPR is used especially by municipalities, and thus for school building design, which is connected with the regulation established by the Dutch institution SBR CUR of the environmental performance for buildings and civil constructions (MPG), and the Dutch national environment-database (NMD) for environmental conditions of materials, processes and building elements (environmental database) [2]. These systems are introduced into building construction to balance the sustainability challenge. But these systems lack the simplicity to use as a practical application. For example, Jalaei & Jrade found that integration of the assessment tool LEED and Building Information Modelling (BIM) was feasible, but only with considerable constraints, and they reduced one of the biggest barriers by eliminating the documentation process [15]. Jalaei & Jrade also state that the general framework of sustainability still misses and is the research is ongoing [15]. Hence, there is some progress, but seemingly the bigger picture still lacks. Marjaba & Chidiac state that “*scientific methods for measurements and criteria to evaluate impacts as a certification systems, that are useful and successful to meet their purpose, cannot be adopted as metrics for performance-based decisions or evaluations*” [16]. Payman & Searcy identified that the analyzed metrics, that have been published in the literature (up to the end of 2012) on green supply management und sustainable supply management, show that the majority of these metrics were used only once, which indicates a lack of agreement on how performance should be measured in these areas [17]. Chang, Lee, & Chen revealed in this context four categories of problems, which include vague definitions, uncertain inventory data, fuzzy environmental impacts and trade-offs, and inaccurate interpretations [18]. New disciplines are necessary to collaborate to increase more balance into the process, that comes from not regularly knowledge domains, such as the emphasis on environmental studies when using systems engineering.

Current approaches to improve the school building performance, besides the use of minimal legislation and regulation rules, are mainly based on specific ambitions of the clients, the use of design quality indicators, and prescribed sustainability assessment tools and guidelines. A main issue however, that should be understood to solve the failures of existing practices into a more holistic perspective, relates especially to recognizing the underlying dynamic patterns of social systems and ecosystems, that exceed largely the levels of classrooms by their multi-level relationship with other scales, such as their surrounded neighborhoods and urban areas. This might however also capture own interpretations of school building design in current processes of decision-making by the architectural synthesis and based on dialogues and consensus. Several researchers recognize interwoven relationships between all these factors, however only a few of them consider the whole picture and existence of underlying patterns, for example, hexagonal forms of pupils' desks, classrooms and school design [19]. Mock & Wernke state that *"we now know that the physical, biological, social and even the economic universe is not random, and that we are beginning to determine just what that underlying "code" is….this includes static elements as well as energy flows, living things, and their behavioral patterns* [20]. Although a geometric theory of everything, as Grand Unified Theory, might be seductive to consider in this context of a search for the bigger picture, it shows also here the underlying social system patterns and the interrelationship with ecosystems and its resilience constraints [21]. For example, to balance end-user needs, institutional school management boards, local communities, ministries, and business interests, this means their social system interrelationships should also be balanced with their relationships with the also multi-level scaled interrelated ecosystems, such as global, regional, local, indoor, and even bodily levels (e.g. cells, immune system). Beside this social and ecosystem place related interconnections, also time related aspects play a role within the different scales of places. For example, such as the stages of design, built, operation and maintenance, in-use, reuse, demolition et cetera and their relationship with building construction places (e.g. structure, indoor walls, facades), and their related spaces (e.g. classrooms and playgrounds), which all should be taken into account by their interrelated levels of scales. Current tools do not take into account these multi-levels scales and relationships to recognize the whole picture and underlying "code" applicable for primary school building design. To solve the persistent physical problems and to meet the balance between the social systems and ecosystems, they should be approached more integrated and multi-level scaled to achieve real sustainable primary school buildings. This complexity needs a dynamic approach that uses multi-level scales to recognize the whole picture and underlying patterns of the relationship between human systems and ecosystems. It should recognize patterns to enable to establish also the functional specifications for clients briefs and building construction morphological design factors into more balance, such as the need for flexibility and to adapt future changes in primary school building design.

So the aim of this article was to develop a theoretical framework to find ground for recognizing the whole picture and underlying code and the relationships to untangle the complexity of interwoven primary school building design failures of existing practices during the process and during the whole life cycle of the buildings, and to deliver sustainability-centered guidelines for real sustainable primary schools (SCGs).

4.2. Development of a theoretical framework

This analytic research defines real sustainable primary school design by recognizing a number of underlying dynamic patterns of similarity to establish some guidelines from a holistic perspective. It recognizes the interrelated multi-level scales of entities by its patterns similarities such as between human needs, sustainable development factors, ecosystems, to establish clients brief specifications and morphological factors for primary school design, qualitatively and quantitatively, and derived from an integrated perspective of interests and characteristics.

4.2.1. Framework characteristics

The relationship of social systems and ecosystem is determined since many years by a number of sustainable development factors and perspectives started by business, such as done by Aguilar [22]. He used four sectors of his taxonomy of the environment: Economic, Technical, Political, and Social: so called ETPS [22]. Subsequently later other abbreviations, such as the STEP abbreviation, followed soon. A variety of taxonomies for sustainable development factors and abbreviations were introduced in the 80's as variations of classifications by: PEST, PESTLE, STEEPLE etc. There is no implied order or priority in any of the formats and some purists claim that STEP or PEST still contain headings, which are appropriate for all situations ([23]. The use of these taxonomy however is integrated nowadays broadly, such as into the Dutch report 'Horizonscan 2050' that describes 150 signals for change and their relationship with STEEP factors of predicted future changes and trends [24]. These factors characterize societal, technological, environmental, economic, political issues [24]. Although a diversity of variations of taxonomies exist, such as Labor (L2), Ethical (E3), Demographic (D) and International (I) factors, these factors, just like cultural aspects, we considered to be part of the sociological factor (for codes see Table 4.1.).

Table 4.1. Overview of the sustainable development characters.

Character	System factor	Examples
P	Political	Political power, governance split incentives (e.g. between government–local governments-school management boards)
E(1)	Economic	Constrained and insufficient budgets for maintenance
S	Sociological	Societal view on education
T	Technological	Technological developments
E(2)	Environmental	Health & safety legislation
L(1)	Legality	Interactions between civilians interests and governmental authorities (e.g. bottom-up and top-down initiatives, justice, human rights)
L(2)	Labor	Changing craftsmanship/human factors in building construction

E(3)	Ethical	Children expose to bad indoor climate
D	Demographic	Demographic population changes (e.g. decline)
I	International	Connection to the world (e.g. Internet of Things)

A common used system, derived from PEST but supplemented with legal and environmental (ecological) factors, is the PESTEL framework. This framework contains six factors: politics, economy, social, technology, environment, and legality. Combinations of these development factors, such as ecological-economic factors, states there are interrelated dependent connections to consider also. In research different kinds of combinations and interrelationships are used, for example, for descriptive concepts that gives insight into dynamic properties of ecological-economic systems. For example, resilience and sustainability are independent concepts, and that more criteria than just resilience have to be taken into account for sustainable development [25], which relates to the dynamic patterns of the factors and interwoven relationships.
Xu, Marinova & Guo state that most exciting studies emphasizes the ecological aspects of resilience, but only by including human activities in the modelling can resilience thinking inform sustainability in a meaningful way [26]. Inspired by positive psychological universal human needs six human needs factors are recognized that relates to sustainable development factors (PESTEL). Robbins uses six human needs by certainty, variety, connection, significance, contribution, and growth, as a human needs pattern of mutual and a hierarchical related factors [27]. These factors illustrates a rather similarity with the six PESTEL factors of sustainable development, within which the similarity patterns, as entities defined, can be recognized well by comparing them (see figure 4.1. and figure 4.2.). Together all factors seems to be interrelated and qualitatively connected by social system and sustainable development interventions, multi-level scaled.

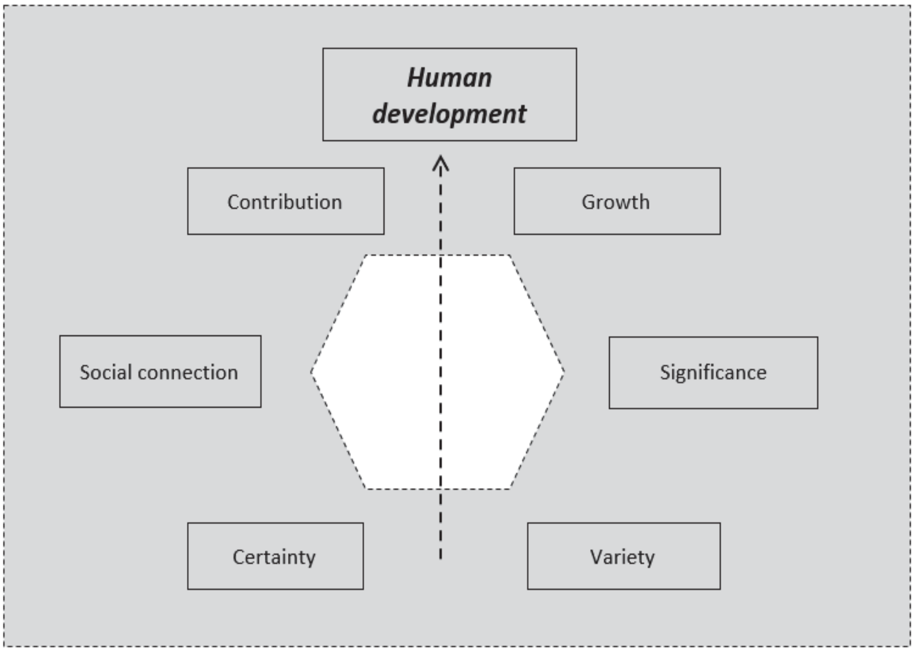

Figure 4.1. Human needs (social system).

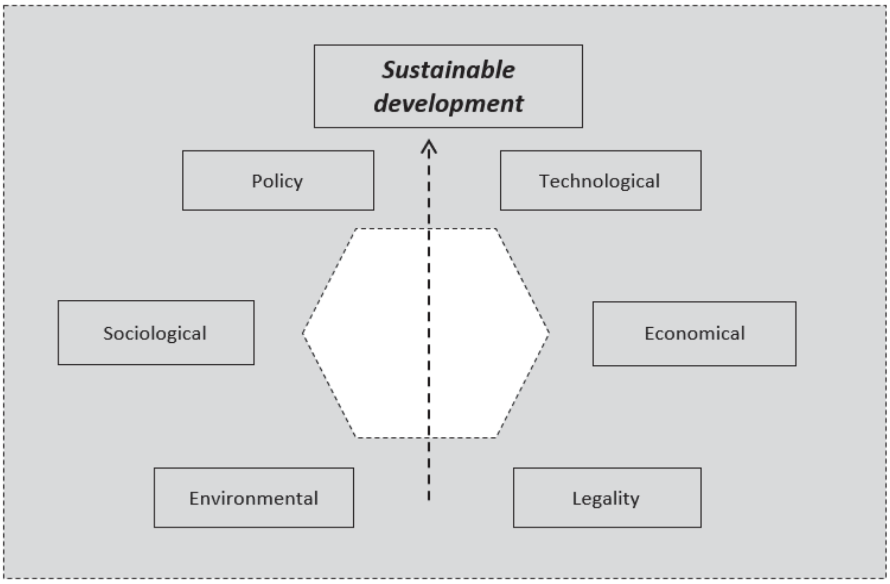

Figure 4.2. Sustainable development.

Although it is preferred to use the more common known PESTEL taxonomy, the similarity with human needs necessitates to change their characters order due to their hierarchical and mutual relationship into ELSEPT (Environmental, Legality, Sociological et cetera):

- The need for certainty relates to the ELSEPT factor of environmental by the biological systems that nature offers, which include, for example, also bodily biochemical cell and immune system processes;
- The need for variety relates to the ELSEPT factor of legality which should guarantee, for example, a certain individual autonomous or heteronomous freedom and flexibility scales between minimal legislation and desired ambitions;
- The need for connection relates to the ELSEPT factor of sociological by social relations such as in (peer)groups, communities, cultures;
- The need for significance relates to the ELSEPT factor of economic by having a special status, such as places, regions et cetera), or having financial ability to realize a new primary school building for the local community;
- The need for contribution relates to the ELSEPT factor of policy such as sustainable benefits by local communities;
- The need for growth relates to the ELSEPT factor of technological, such as new technological features.

The resemblance between the human needs factors with sustainable development factors is remarkable. This resemblance challenged us to further research qualitatively and quantitatively. Noticed is that when the sustainable development factors are just like human needs hierarchical and mutual related, also their polarities might be characterized as similar by their up- and downwards relationship, and their in- and outwards relationship [28]. It explains why the four factors of STEP or PEST also makes sense from a polarity perspective.

A multi-level scaled relationship of interrelated social system connections (individual, groups, community, society et cetera) per definition intervenes with ecosystems levels of scales (e.g. bodily, indoor, local, regional). Every human intervention relates to one of more levels of ecosystems (within or without rehabilitee of the system when exceeding the constraints). From sociological ecology derived social system related scale of intra- and intersubjective experiences (sensory reception of all senses), or a psychological associative cognitive experience (thinking about the perception), per definition the time related impact also relates to an ecosystem related scale of (inter)objective biophysical (bodily) experience of the environment. From this perspective it should be noticed that all senses are taken into account for a good balance instead of only dominance by visual building material assessment, see [29]. End-users of school buildings experience their physical learning environments socially (the social learning environment) and physically (the physical learning environment), but the main communication tool is still a drawing such as used in current construction chain (2D and 3D), which is a shortcoming to balance all senses. The hierarchical mutual related social system of six human needs and bodily ecosystem illustrates here how this mechanism for individual end-users, which conditions are important influences to fulfil their needs psychologically and physiologically, and how biophysically factors of environmental circumstances play a role for them bodily (and by indoor conditions et cetera). This assumes an inseparable interrelationship between social systems an ecosystems for individuals, but considered from a multilevel scaled systems, also groups, communities and society. Referring to the weblog School of Wisdom "The Ultimate Paradigm Shift state that the free will of the individual in connection with the infinite is now primary" [30]. Anderies states "*an Anthropocene era where human activities shape the planetary system in which built and natural environments are becoming more tightly linked across scales, these complex systems need to be considered as elements in a global network, i.e. as a coupled social–ecological system (SES) at the global scale"* [31]. The social system and ecosystems are recognizable here as well as into the global relationship.

From a social system perspective the upwards driver is, as a mechanism of hierarchical and mutual relationship, a system condition that provides a certain balance to fulfil all human needs in harmony, searching for homeostasis constantly. Independent of the extent to which all needs are fulfilled a balance will be found by the fulfilled needs from a bottom-up approach hierarchically and mutually. That is, the human need for growth is stated by the desired development perspective (see Figure 4.1). But, development and growth are not the same. Sustainable development determines an upwards driver for all sustainable development factors, while sustainable growth (e.g. technological development) is just one of the factors. According to Daly, "*growth can increasing quantitatively in a physical point of view, while development is more a qualitative improvement or unfolding of potentialities*", and "*An economy can grow without general developing, or, developing without growth, or, both or neither"* [32]. A four-dimensional model is developed for sustainability by economic, social, ecological and cultural dimensions see [33]. To identify their polarities, they can be recognized by the similarities between human needs and sustainable development factors. For example, the 'economic' factor interrelates with the 'sociological' factor, similar to feeling significance interrelates to feeling social connected. Hence, social human systems and sustainable development factor share a similar dynamic. It becomes more complex when sustainable development factors, such as economic, fulfils one of the other human needs then expected by similarity, such as economic fulfils the need for certainty. The interrelation of substituted factors, such as the economic factor that fulfils in fact the need for significance (think about status), also fulfils the need for certainty by 'false' interrelationships. Having money simply means feeling significance from an egoistic perspective, and secondly feeling certain from a hedonic perspective. To find support for this complex interpretation of dynamic interrelationships between social systems and ecosystems, we connect these pattern polarities to psychological system approaches. For example, Venhoeven, Bolderdijk, & Steg refers to egoistic, altruistic, hedonic and biospheric patterns, as paradox patterns of relationships [34]. Snelgar refers to the egoistic, altruistic and biospheric environmental concerns [35]. Both, these pattern similarities are recognizable within the sustainable development mechanism as outwards directed sociological (relates to social systems) and inwards directed economic (self-fulfilling) characteristics, and as downwards directed environmental (relates to ecosystems), and upwards directed technological factor polarity characteristics. Identifiable is the relationship between altruistic and the human need for social connection, and its relationship with the ELSEPT sociological factor. Also identifiable is the relationship between the egoistic (inwards directed) human need for significance, and the economic development factors (lose from the false need for certainty). Hence, biospheric can be related to the need for environmental concerns, while hedonic is more or less a factor which relates to the total fulfilment of needs, the driver for development, but especially to growth, such as the drive for development of new technology. The comparable relationships between the human needs and sustainable development factors assume the existence of an underlying system similarity pattern by their internal relationships. Hence, there is theoretical ground to state that a system approach by using similarity characteristics can be derived from a complex (interrelated dynamic) adaptive (substituting) mechanism of different levels of scales and patterns to balance.

Social systems relate thus hierarchically (up- and downwards directed) and mutually (in-and outwards directed) as a constant homeostatic search for balance between the ecosystems constraints or beyond (ecosystems prefer to rehabilitee). Due to their interrelated connections and time relationship of influences and human interventions (impact), transformations occur within the levels of different interacting ecosystems. Hassler & Kohler state "*the speed of the transformations is not linear but instead it could be seen as a succession of gradual and rapid changes i.e. slow moving risks and disturbances versus rapid extreme events*" [36]. Here we arrived at the Human Ecology, which contribute to describe the interrelated connections as an interdisciplinary and transdisciplinary study of relationships between humans and their natural, social, and built environments. It considers in general two main approaches:

1. social system (knowledge, social organization, population, and values);
2. ecosystem (air, plants, water, soil, animals, micro-organisms, human–built structures).

From an ecological perspective, humanity is an ecosystem itself. Individuals have their own ecosystems and interactions with the environment takes place within the resilience of global, regional, local and indoor environments from an interrelated perspective of scales (e.g. bodily processes within indoor conditions et cetera). Hence, just like ecosystems, also social systems (e.g. society, local community, end-users, and individuals) relate to the continuum of small and large ecosystems, but their position is always enclosed and dependent of the surrounded ecosystems. Because of their enclosed multi-level scaled relationships, the connections between all these social and ecosystem processes might be seen as chaos-theoretical circumstances, but their enclosed relationship is clear. The grade of needs fulfilment depends thus of the conditions and circumstances, such as the way human are be able to intervene autonomously or heteronomously to improve their experiences of well-being performance. Theoretically also cognitive and health performance can be influenced, but are mainly unaware factors. Obviously human needs can be fulfilled temporarily by psychological (e.g. motivation), physiological (e.g. warmth), and bodily biological (e.g. sports) interrelated factors.

Because of the increasing availability of intra- and intersubjective fulfilment of needs by cognitive and sensory experienced stimuli, in current time of welfare for a part of the worlds' population, the fulfilment is getting exceeded by all the opportunities (e.g. availability of fruit from all over the world instead of from biological origin of an own garden). This increased conditions decrease the fulfilment. Raudsepp-Hearne et al. found a paradox that human well-being has increased despite large global decline in most ecosystem services, instead of that environmental degradation lead to decline in well-being [37]. Hence, a paradox, or polarity unbalance, is recognizable well here by the need for human growth (social system) at the expense of natural environments (ecosystems), which can be explained from the interrelated polarities and entity similarities. Williams suggests that human consciousness as unique and different than the natural world but constrained by natural limits, and as environmental sociologists state, that the human and social systems are deeply connected to nature, and conflict with cognitive patterns: '*there might be also a remarkable contradiction or paradox to human consciousness as unique and different than the natural world'* [38]. This contradiction, or paradox, states that the sustainable development includes a contradiction between social system development and ecosystem development. A point to consider from this impact of a lack of fulfilment is stated by the existence of a time lag after the ecosystem service degradation and before human well-being is affected, so called the environmentalist's paradox [37]. The term well-being, which is mainly related to physiological sensory based experiences, is used differently for welfare and/or for health aspects. It includes thus a mixture of social and ecosystem related associations. It should be noticed that the underlying pattern of the complex mechanism should be understood well and that from the continuum of a psychological (subjective), physiological and biological (objective) perspective the physiological needs more explanation whether it is more subjective than objective. For example, the WELL Building Standard Educational Facilities (Pilot A) describes a standard modified for offices, where well-being is related to worker health, performance and motivation [39], which are totally different intervening parameters. There is no evidence that 'green buildings' associated with ecological building materials and energy systems are more comfortable [40], which states their differences obviously. Raudsepp-Hearne et al. state that the technology has decoupled well-being from nature [37]. That is, the underlying mechanisms that decoupled well-being from nature relate to the way of satisfaction, rather by fast new technological inventions than by means of slow or unpredictable gifts from nature. For example, rather enjoying a steady room temperature or a warm douche, than a cold natural start in the morning. This mechanism makes it possible to increase the awareness of behavioral pattern and human needs based interventions. For example, it is not the technological development, but the way how technological development fulfils our needs for growth psychologically and physiologically more quickly, by pleasurable experiences. Famous philosopher

Tomas Hobbes' wrote into his book Leviathan in 1651 that well-being is only experienced after a period of making efforts, such as after a period of fighting followed subsequently by a period of rest and well-being, until the new period of well-being experiences does not fulfil anymore, and the circle starts again. This variable cyclical process, within a polarity system of fight and rest, lead to the described paradox. This is important to understand for primary school building design, such as conflicting well-being experiences in classroom temperatures with natural fluctuating values that might be better for to improve end-users health. For example, Marken Lichtenbelt et al. found in cold-activated brown adipose tissue in healthy men a relationship between obese and regular used indoor temperature [41]. This might explain that most comfortable experiences can conflict with biological processes and cognitive performances, such as found by Wargocki, Wyon, Matysiak, & Irgens by reducing the temperature from 23.6 C to 20 C, which tented to reduce 10% number of committed errors in acoustic proofreading [42]. Well-being is thus more social system and subjective related when related to temporarily sensory (fast) experiences, and more objective when related to (slow) unaware experiences.

The constraints of resilience between social systems and ecosystems relate to sustainable development factors. Unbalanced factors might cause suddenly disruptive changed ecosystems, which illustrates the pattern mechanism of resilience, which is not linear and increasingly links to discontinuities, referring to the theory of Panarchy [43]. Xu, Marinova & Guo [26] describe psychological resilience, engineering resilience, resilience engineering, ecological resilience, social resilience, economical resilience, and social ecological resilience, and refer to the importance of these systems and studies (see [32], and the vulnerability of resilience in systems, such as the suddenly break down by economic and social unbalances, but in conclusion they state that a main question still is how to identify and manage the key drivers and elements of resilience [26]. Hassler & Kohler describe the context-specific definitions of resilience, such as in physical material systems, ecological systems, social systems, individual systems, and noted how resilience also has become a politically significant notion [36]. Sustainability and resilience should be considered integrative [45]. Ecological resilience is determined by different factors, such as the existence of biodiversity, which makes ecosystems resilience. But human-built structures relate also to the need for diversity by their variety in building morphology in the context of villages or cities, as well as primary school buildings, which includes their structure, element and material diversity. Coping with either natural or built environments in isolation is extremely challenging in its own right (e.g. built environments at different scales: a single building, a collection of buildings, a neighborhood or a city are in themselves very complex [31]. Hence, different multi-level scales of sustainable development factors and resilience are the same and should be approached interrelated by the different enclosed multi-level scales of human systems and ecosystems. Xu, Marinova & Guo conclude that "*sustainability is about a harmonious relationship between natural and human world, which relies largely on social-ecological systems (SESs) being able to withstand the increasing external uncertainties and perturbations"* [26].

The sustainable development factors are determined between the continuums of ecosystems scales and social system scales interrelationships. From a social system scale perspective, the sustainable development factor is best described by *sociological.* This also refers to the multi-level scaled social systems by the need for social connection, which set a next step in the search for similarities. From an ecosystem scale perspective the related sustainable development factor is best described by *environmental*. Sociological scales and environmental scales relate both to resilience within all ELSEPT factors and form together the two main scale systems of incorporated resilience, within which the other factors are subdivided from the field of sustainable development resilience (see Figure 4.3.).

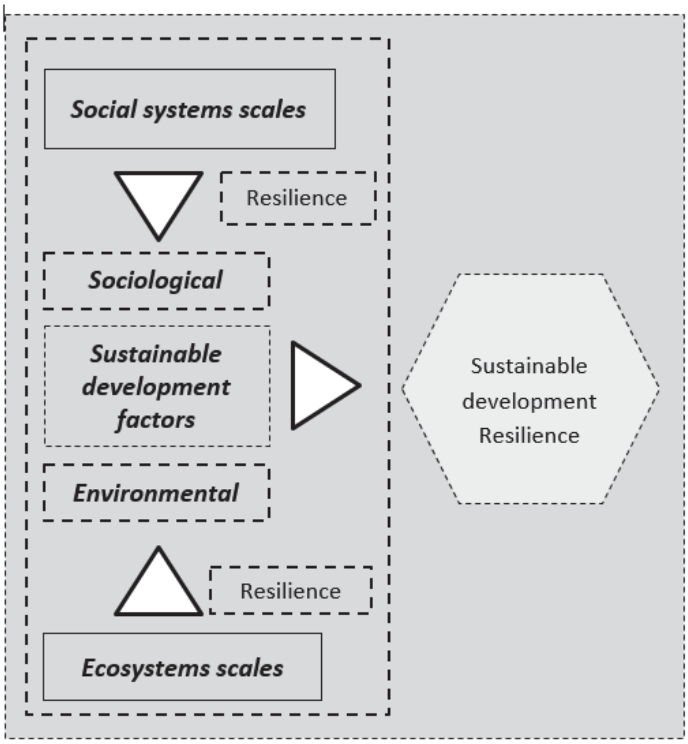

Figure 4.3. Social system and Ecosystem relationship with Sustainable development and resilience.

4.2.2. Qualitative systems characteristics

To enhance sustainable development balance it is important to consider this from the point of view whether their context is more stable or unstable. Xu, Marinova & Guo argue that balance can be reached by paying more attention to sociological and ecological factors [26]. The social system relates to the sociological sustainable development factor, and to the human need for social connection. The ecosystem relates to the environmental factors and the human need for certainty. Hence, both systems relate to each other whereby the factor legality can ensure a certain minimal level of, for example security, safety and trust, to balance the systems, using the constraints of minimal legislation rules and high ambitions. From this point of view the factor legality relates strongly to the need for variety. The sustainable development factor legality thus also functions into this position as resilience for the social system and ecosystem. Gunderson & Holling state that "*a variety of arrangements and rules that have evolved in different societies to harmonize the relation between people and nature*" [44], which states how variety is connected to social systems and ecosystems. The factor legality should contribute into stabilizing ecosystems to protect humanity from nature disasters, such as from the collapse of ecosystems. In this way so far all these three factors contribute to stability. The two sustainable development factors of environmental, and sociological seems to be related more to the product factors, the legal factor switches dualistically between steady stated product design based legislation, from design quality guidelines to process decision-maker based undefined preferences by a variety of different multi-level scaled ambitions (see Figure 4.4.).

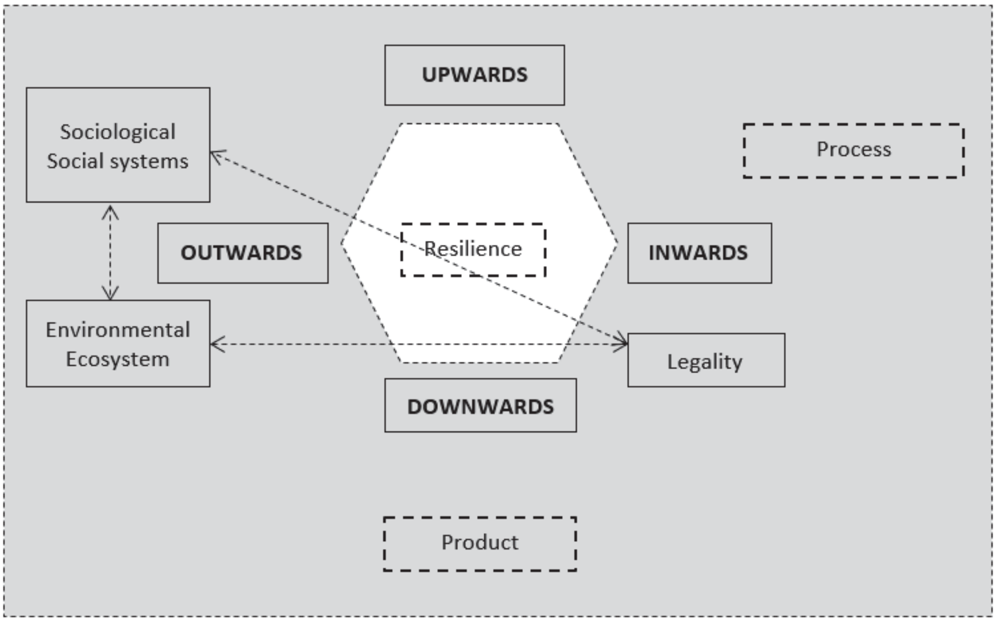

Figure 4.4. Scheme of polarities and product and process relationship with the dualistic legality factor.

The other factors, such as politics, economic and technology are more related to the process factors due to their influences, such as political influences at legislation rules. For example, the crisis we face today is often seen as a result of primarily the financial system, but also of our political systems. The unstable factors, economic, political, and technological, are the factors which cause instability when crossing the borders of resilience, but also the legal factor when ambitions are fluctuating influenced too much by stakeholders into decision-making processes. This point also relates to the fulfilment of human needs, such as caused by wanting to be too significant, to contribute too much, and to grow too fast. Within this pattern polarity mechanism of striving for balance, hierarchically and mutually, these interrelated similarity factors (stated as entities), can be derived from the social system by human needs, and their impact at ecosystems derived by the sustainable development factors human impacts.

In order to position 'the term' sustainability within the context of sustainable development, sustainability in fact can be considered as the stability of the whole of ecosystems and social systems, and within it a certain natural resilience. Multi-level scaled the ELSEPT factors itself also have resilience, but within the constraints of all balanced factors, as well as the human needs have. When ecosystems are influenced by social system interventions, the ELSEPT factors can be used to influence the social and ecosystems, so that they can rehabilitee and the systems become stable again. That also means, when resilience constraints are exceeded, sustainable development is out of control and social and ecosystems becomes unstable, possible ending into a new stable ecosystems with new conditions or collapse suddenly (see [31) and thus might be simplified stated as an unpredictable and a situation of future uncertainty. To illustrate the relationship between the instability of the social systems and ecosystems, the need for certainty (downwards directed needs), which relates to the ecosystems, creates uncertainty, such as by means of the unknown effects of climate change such as melting artic ice, or fast distinction of living species. The three stability factors of human needs seems to satisfy the needs slowly but long by their impacts, while in comparison the three instability factors satisfy fast and short. Sustainability is thus, from this point of view, a stable system that can be determined especially by the factors Environmental (certainty), Legal (variety) and Sociological (social connection), but becomes unstable by Economic (significance), Political (contribution), and Technological (growth) when crossed the resilience boundaries. For example, when social systems are too much influenced by environmental (e.g. changing road traffic near the school building), legal (e.g. unbalanced school building requirements by different governmental ministries) changed and sociological (e.g. demographic changes), the local community will search for compensation to balance this unstable situation by adding impacts from the other factors, such as new policy (e.g. establishing new integrated child-centers instead of multi-functional accommodations, new economic (e.g. change schools into townhouses), and new technology (e.g. use augmented reality in classrooms), which destabilizes the situation even more by upwards interventions. This all means that current sustainable development system factors from this perspective are 'top-heavy' due to increasing possibilities to use these exiting and stimulating economic, policy and technology to compensate the deeper unbalance of needs for certainty, variety and (social) connection (see Figure 4.5.). Both systems now can be related integrative to building construction products and processes, such as to primary school building design (see Figure 4.6.).

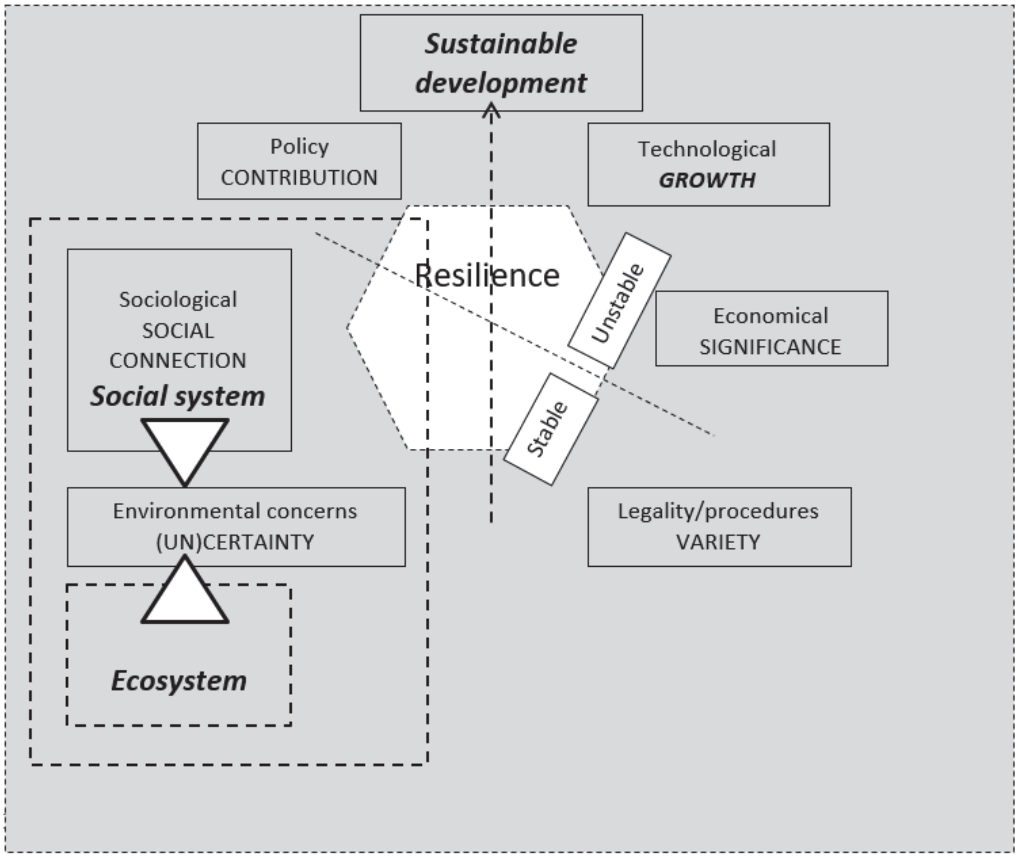

Figure 4.5. Stable and unstable factors.

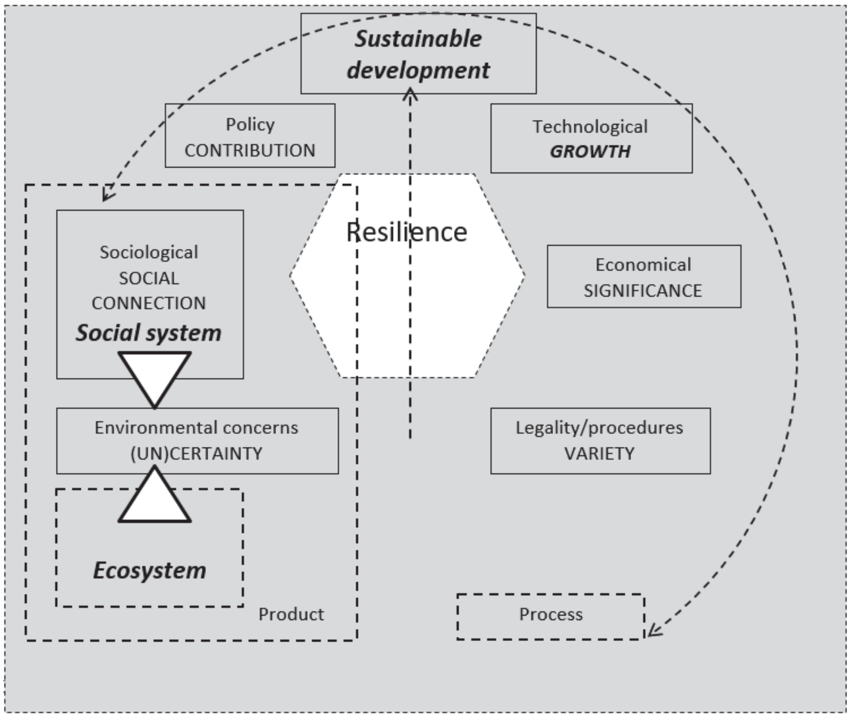

Figure 4.6. Product and process factors.

Considering the resilience between both, the ecosystems and human systems (described as the field of environmental concerns and (un)certainty when exceed), it is recognizable how resilience as an single entity made by the factors legality and variety relates to the product by the field of minimal legislation and ambitions, and the process by the field of the relationship with the downwards polarity of environmental and inwards polarity of economic constraints (see Figure 4.7.).

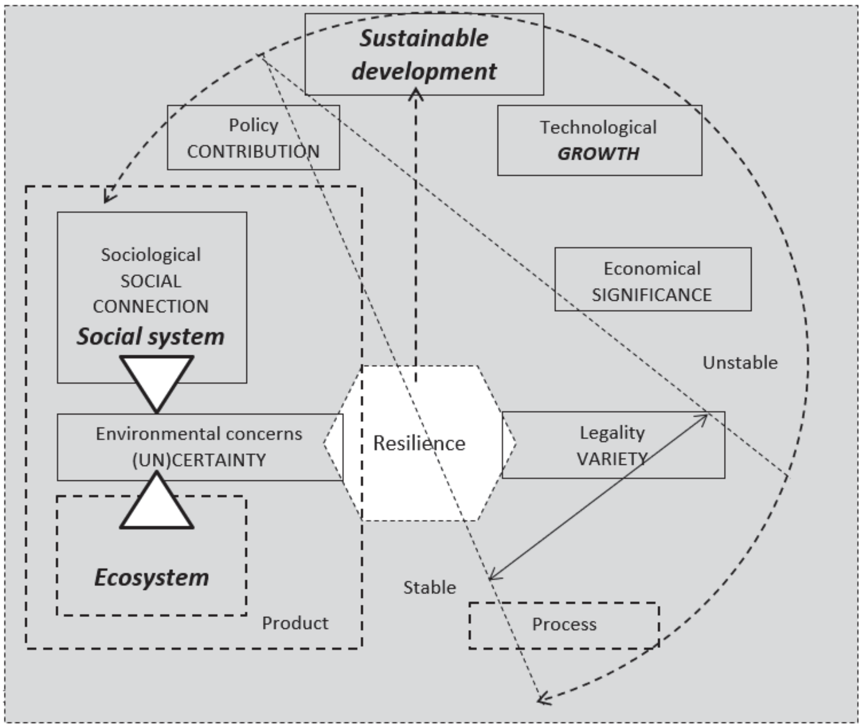

Figure 4.7. Integrative model of multi-level scales of resilience.

Similarity patterns are recognized between human systems, sustainable development and the ecosystems from different perspectives, that indicates that stable ecosystems can be associated with continuity; variety with diversity, and connection with coherence. Subsequently, the other factors can be associated as significance with (sub)species, contribution with wealth, and growth with extension (see figure 4.8.). Ecosystems are becoming environmental concerns (uncertainty) when the stability is deteriorated and threatened by means of human exceeding interventions, expressed in terms of association with (un)certainty by scarcity; variety with singularity; connection with disconnection; which also relates to increasing the instability by the association of significance with domination; contribution with withdraw effects of species; and growth with extinction. Although, this way of reasoning gains a lot of generalizing, the point here is that there is a mutual relationship between the ecosystem human-built structure impacts and environmental concerns whether sustainable development or a human needs approach is used (see Figure 4.9.).

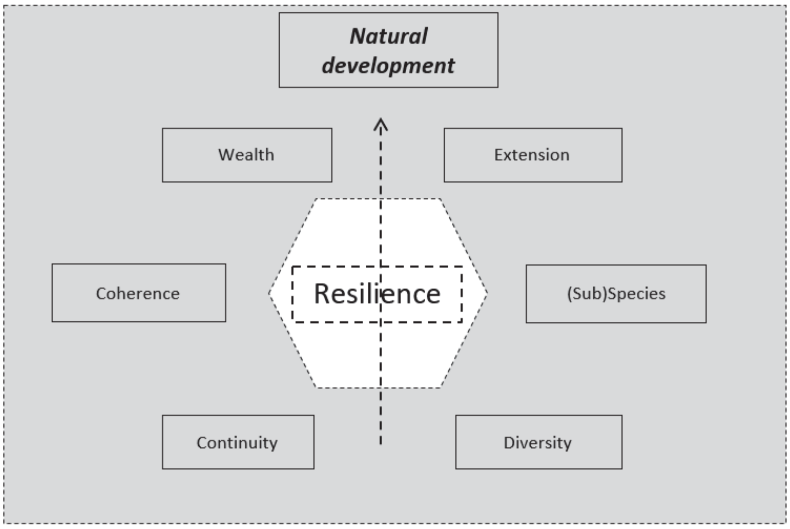

Figure 4.8. Ecosystem natural development.

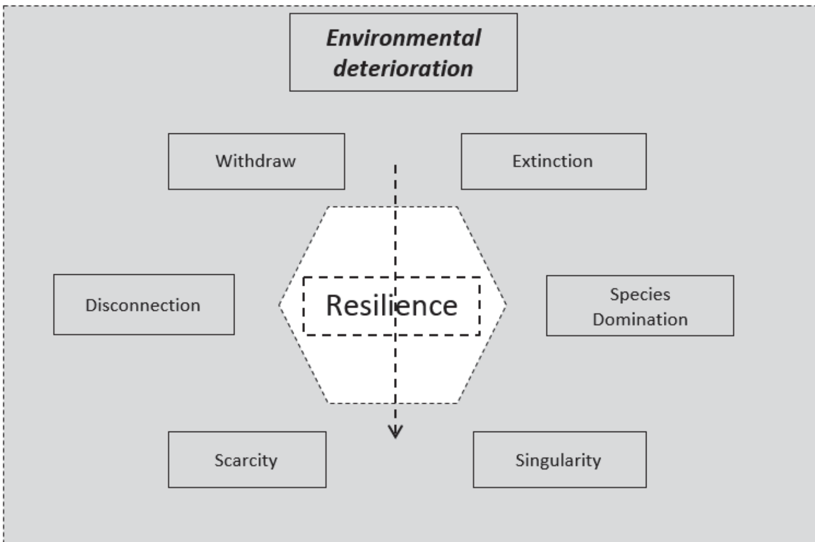

Figure 4.9. Environmental concerns.

Primary school building design is an iterative process of brief specifications and design stages. In generally it starts with a conceptual level of collecting functional specifications, the initiation phase. This inventory of requirements and opportunities contain the first steps of client briefs, that is growing bigger by filling more detailed an iteratively the functional specifications, by describing more precisely the functionality; the aesthetical and social-cultural values; the financial constraints; the sustainability ambitions; and the technical facilities. Human-built structures, such as a primary school building, are approached regularly as an one-time event of designing a building that can be used unchanged for many years. Although in present design of school buildings fast changes will affect by new born specifications, the structure, its flexibility, its expandability, its connection with surroundings, and its adaptability to deal with these changes, trends and innovations. When buildings are considered to be modified periodically, such as by trends related ELSEPT factors of economic, political, and technological influences such as the Dutch report 'Horizon scan 2050' presents 150 signals for change [24], decision-makers of school building processes should consider these building rather better as living organisms. Referring to McGinley buildings become more intelligent than their occupants and designers, and a morphogenetic architecture framework for intelligent buildings is proposed [46]. This future prediction seems to be a logical pathway when primary school building morphology, in relationship with ecosystems and social system similarity patterns, should be balanced optimally. In relationship with standard client briefs, the aesthetical, social, functional, technical, sustainable and financial sections show a remarkable self-similarity, like a fractal, with human needs, sustainable developmental and ecosystems factors of stability/instability and product/process. Considering the different values, Ott suggested a better ethical focus on human made worlds and nature through the use of Hannah Arendt's theory of the vita activita [47]. As in briefs prescribed regularly, for example, sustainable development related environmental values, legal values, sociological values, economic values, political values, and technological values, it links to functional (certainty); aesthetical (variety); social (connection); financial (significance); sustainable (contribution); and technical (growth) factors. Hence, it is a small step to link these brief sections to the sustainable development ELSEPT factors. The recognized unbalance between the stable and unstable ELSEPT factors are considered to be influencing school building design functionality similarly.

To relate the ELSEPT factors to school building design, a number of options are deduced to optimize the balance by (1) enlarging the stability factors of development by enhancing (and control) the environmental values, legal values, and sociological values; (2) curb the economic, political, and technological influences (e.g. influencing consumer behavior); (3) optimizing all sustainable development factors and gain more balance by reconsidering all factors integrative; and (4) staying on current pathway, which means choosing for a total collapse or entering a new system. Economic factors relate as described earlier to the need for significance, and are yet main fulfillers of the need for certainty. In fact the false fulfillers of the need for certainty affects indirectly all human needs. It is not expected that this will be changed by political interventions as long as our monetary system exists. A sustainable society will however not arise spontaneously, due to slow responding ecosystems, such as climate change effects. Environmental problems should not be solved by technophylic design [48]. Fiksel states that "*there is an urgent need for a better understanding of the dynamic, adaptive behavior of complex systems*" and states that "*the resilience in the* *face of disruptions, recognizing that steady-state sustainability models are simplistic*" [45]. Hence, only option (3) sustains, which incorporates an adjusted approach that considers the dynamic (e.g. polarity characteristics), adaptive behavior (human needs) and complex systems (e.g. the similarity patterns), and it recognizes that current models (e.g. LCAs) are too steady-state.

4.2.3. Quantitative systems characteristics

The social system related human needs, sustainable development factors and ecosystem, as well as a building construction related entities that show similarities such as by client brief sections, does not only relate qualitatively, but also quantitatively by their ratio similarities. Weighting factors can be recognized by their qualitative similarities of hierarchical and mutual relationships. The strongest need for certainty, for example, relates to the environmental factor of sustainable development, and to the ecosystem of continuity as most important entity for keeping the ecosystem stable. Although the used figures illustrate a hexagonal model without a ratio, the profound principle describes a more or less spiral dynamic mechanism due to the mechanism of upwards polarities, which relates also quantitatively by their similarities of importance. In order to quantify the sustainable development factors, the golden ratio divine proportion, or golden mean, is used as a theoretical hypothesis to consider its value for this purpose. Also considered is the Integrative Sustainability Triangle by Kleine & Hauff, which describe the relationship of society, ecology, and economy, and generates a triple bottom line approach for the collection, systematization, quantification, and evaluation of all the relevant issues found within corporate environment [49]. However, this approach lacks an theoretical base of political, technological and legal influences. Therefor we used a 'natural' approach by using the golden mean reciprocal values, determined by the Fibonacci integer sequence +5+8+13+21+34+55, which makes a total of 136 et cetera. The calculated value for certainty, for example, makes 55/136 x100% = 40%. The characters of 1+1+2+3 although are not used because of the inaccurate break (see Figure 4.10.).

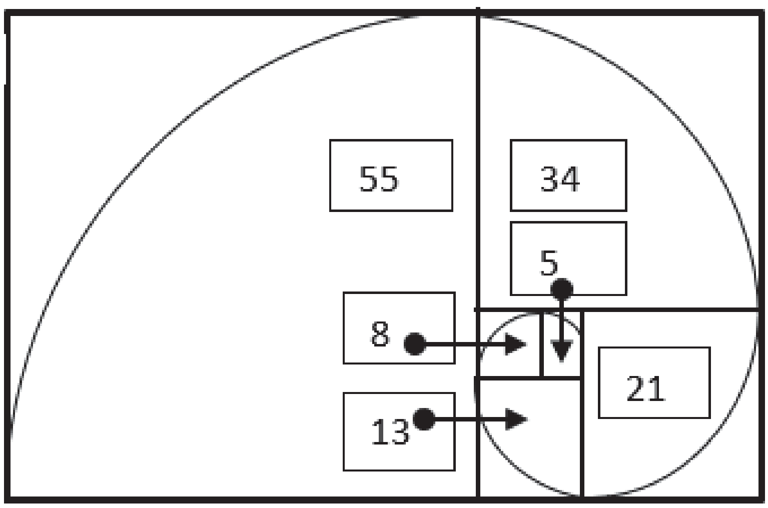

Figure 4.10. Golden mean.

CHAPTER 4: Environmental interests

When added the calculated values as weighting factors to the qualified entities. Remarkable complex links illustrate the complexity of the dynamics between these factors when they all relate hierarchically and mutually, and also substitute (such as false certainty). For example, the need for certainty can be fulfilled without taken into account the environmental factors influences at the ecosystem continuity. The entity factors that relate to the brief sections at multi-level scales, means that intra- and intersubjective and (inter)objective needs and interests from end-users, school management boards, society should be considered at all these levels in the different sections of the brief by their quantified impacts (see Table 4.2.).

Table 4.2. Qualitative entities and quantitative ratios.

Sustainable development quantification table				
Social system factors (sociological related)	**Sustainable Development factors**	**Ecosystem factors (environmental related)**	**Current client brief sections**	**Calculated values**
Certainty	Environmental	Continuity	Functional	55/136 = 40%
Variety	Legality	Diversity	Aesthetical	34/135 = 25%
Connection	Sociology	Coherence	Social	21/136 = 15%
Significance	Economy	Subspecies	Financial	13/136 = 10%
Contribution	Politics	Wealth	Sustainable	8/136 = 6%
Growth	Technology	Extension	Technical	5/136 = 4%

The table shows the percentages relationship with the entities. For example, the 40% calculated ratio relates to the first entity weighting the experienced fulfilment of the need for certainty, the environmental factor impact, and ecosystem continuity, which means a balance of ratio's should establish the product primary school building, that involves all multi-level scaled factors (e.g. by their different stakeholders, the time related whole-life stages of spaces, and places, and impacts) in balance with the other entities. Therefore it is needed to distinguish only from this perspective the physical from the social environment because they always remain interrelated connected. For example, a child who is afraid for the teacher (a social experience) and hide itself into a corner of the classroom (a physiological sensory experience). In order to distinguish the physical environmental shells a social system of human needs is used for the intra- and intersubjective experiences of learning place/desk, classroom, interior rooms, exterior, playground, surroundings, see [28], and for the material elements that makes the scale levels of places for the (inter)objective ecosystem related entities are used the levels of scales of: bodily, furniture, indoor partitioning, building elements, outdoor constructions and roads. Habraken distinguishes: Configuration (e.g. interior arrangement, floorplan), Nominal classes (e.g. building elements) and Spaces within (e.g. room) [50]. Recognizable is (1) the objective ecosystem relationship with the places (material and energy related values of building construction components made by local, regional and global manufactured resources), and (2) the subjective human system relationship with the spaces (sensory effects, emotions, thoughts experiences). Because of these multi-level scaled patterns, every factor relates also to the decision-making process stakeholders, which might give a glimpse of why current processes due to its complexity should not give too much room for own interpretations, such as by dialogues and consensus, when underlying patterns exist.

Remarkable is the similarity of the calculated 10% for the economic factor, which comes close to Brundtland Commission in 1987 calculated 5-10%. Although a polarity of contradictions has been identified by Daly, such as he described by: "*Since the release of the Brundtland Commission Report in 1987, the Commission needed to maintain unity of political interests, and it sacrificed critical attention to "glaring contradictions" in its own report"* [32]. Daly "*argues that it is impossible to respect ecological limits and to have growth in the world economy by a factor of 5 or 10"* [32]. But, recognizable is how the resilience within the dynamic of sustainable development polarities still gives room for 10% economic growth when all other factors together are balanced well (see Table 4.2). And, also remarkable is that the three bottom line factors of environmental, legal, and sociological together are 80% which is close to common sense rule of 80-20 stable/instable.

This approach makes also clear why current client briefs are unbalanced when these ratios are not considered from a multi-level scale and integrated perspective. For example, school buildings are designed for at least 40 years economic value, whereby the technical value of the school building structure is more than 100 years, the education policy seems to be changed regularly by every four years political elections, and the building functionality might be less than 10 years (for offices the period is reduced to 5 years). This advocates also a quantitative calculated balance, that also can be used for quantifying the flexibility in new school building designs to enlarge the school building usability period, and at least to balance the brief sections more rationally and adjusted to each other. That also touches the building morphology, its design, and decisions-makers preferences.

4.2.4. Synthesis of systems characteristics

Common used terms in building construction design relate to the ELSEPT factors and their specific entity. For example, environmental factors relate to building construction ecology or ecological buildings. Technological factors relate to building construction technology or intelligent buildings. Hence, it is recognizable that the ecological related entity provides a stable product from ecosystem perspective (e.g. a circular natural system approach), and the technological related entity provides an instable product, due to the fast technological changes during its whole-life process. When both of these two extremes (from a polarity perspective) are related to human built structure knowledge disciplines (product) and to innovation directed disciplines (process), it illustrates how the disciplines interrelate with the system products and processes. This gives interesting insights in current processes and stakeholders positions and impacts. For example, the urban planning policy always had a dominant top-down position that framed the school building location and situation, and its morphology by prescribed constraints. When building construction terms and domains are related to the knowledge discipline domains, similarity patterns can be recognized well (see Figure 4.11. and Figure 4.12.).

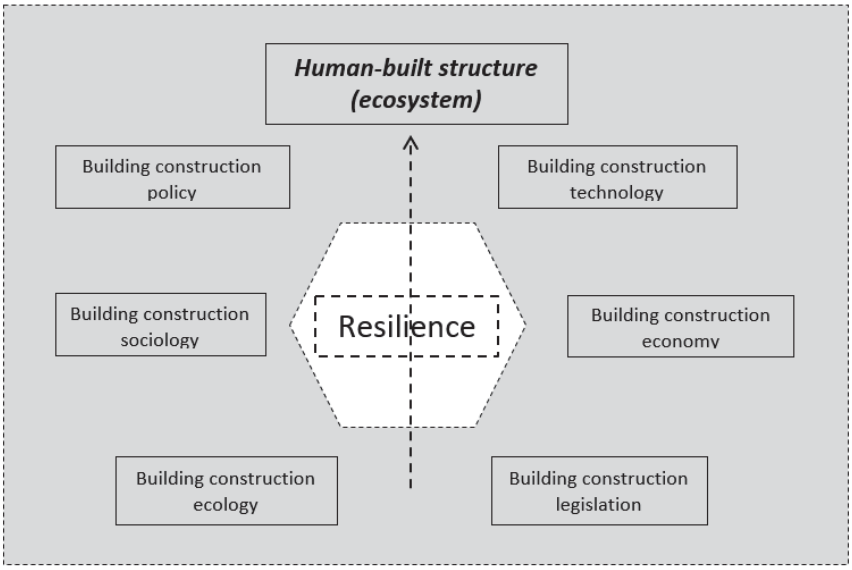

Figure 4.11. ELSEPT relationship.

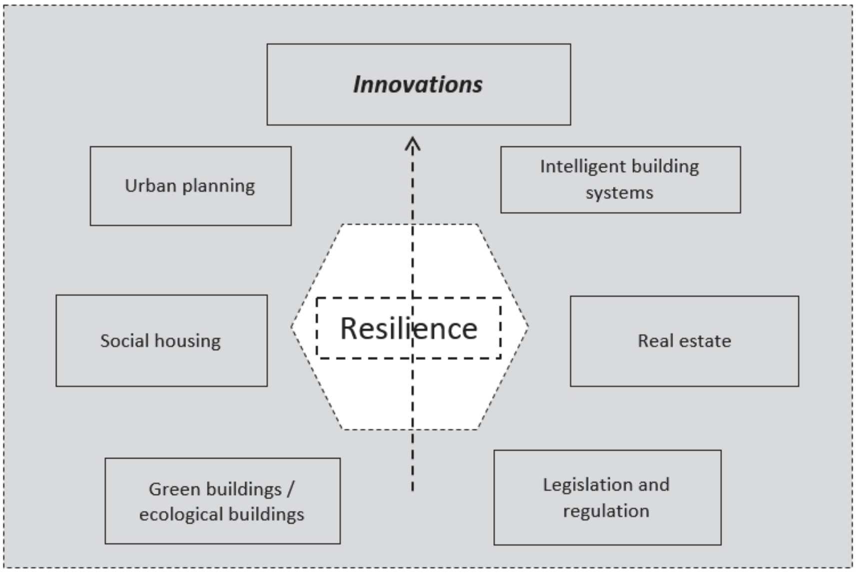

Figure 4.12. Building construction innovation.

Besides these material and energy related factors, that makes the places and spaces seen as (inter)objective and intra- and intersubjective spatial design, also time related effects, such as whole-life approaches, should be involved during their whole-life of decision-making stages such as initiative, design, construct, operation and maintenance, refurbishment, reuse, rebuilt, and demolition stages. Beadle et al. state "*that changes, such as future values are, might be social, environmental or economic, all elements of sustainability, but they will affect the way we construct and use buildings at the moment the majority of buildings are designed and constructed to suit a particular use at a certain time, with no thought for the future*" [51]. These stages also can be distinguished further by daily operation activities, yearly maintenance, short time preventive or long time technical maintenance et cetera. This perspective makes clear how product and process are interrelated by place/space and time, and should be considered more integrated multi-level scaled also from the smallest buildings elements. That is, that the different physical learning environmental related indoor and outdoor shells, such as defined by the desks, (class)rooms, interior spaces, exterior building, play garden and surroundings, should be considered separately, as well as a whole approach by their objective place and subjective space, time and impact relationships from the underlying polarity to balance. Furthermore these place and space levels of scales of structure, morphology, building elements and materials relate to the scales of bodily, indoor, local and regional (and global) ecosystems conditions, and its own time related circumstances and changes, such as by weather, fungi, moisture, and pollen. Hence, the building interact with the multi-levels social systems, its impact at the environment, and the impacts of the environmental circumstances and conditions affecting the learning environment scales. It might not be the question whether buildings should interact with their environment but how they can strengthen each other (e.g. by using permaculture). In order to verify this synthesis on the pathway to guidelines that can realize real sustainable primary schools, the definition of Clements-Croome is used, although that describes intelligent buildings and surely meant as an all factor balanced approach by: "*they should be (1) sustainable, (2) healthy, (3) technological aware, (4) meet the needs of occupants and business, and that they should be (5) flexible and (6) adaptable to deal with change*" [52]. In fact Clements-Croome [52] defines the need for a stable system of sustainable development factors by (1) environmental factors (certainty), that takes into account (2) more attention for the smallest (e.g. cell/body) ecosystems (certainty), (3) give room for the less instable determinants, such as new technological innovations (growth), (4) give more attention to sociological factors (connection), (5) pay attention to flexibility (variety), and pay attention to adaptable (contribution). Intelligent buildings themselves are special to represent this needs (significance), and the shift from sustainable building (ecosystem related) to intelligent buildings (human and ecosystem related). The term resilience bridges sustainability to building construction by different terms, such as flexibility and being adaptive to deal with changes, which considers from this perspective the definition as that it comes close to the recognized similarity patterns.

The established pattern similarities and synthesis offer yet ground for to state an integrative perspective and method to define real sustainable primary school building design as a perspective that considers the material systems (e.g. structure, morphology, elements and materials) and the energy system (e.g. using passive solar power, natural ventilation systems) more integrated with the recognized entities, such as human needs and the ELSEPT factors. The similarity can be recognized by using the six entities, such as flexibility relates to variety, adaptability to contribution (to create new opportunities) and so on. These examples shows how human-built structures, in this case primary school buildings, relate to the morphological factors, that can be used for improving and enhancing a model such as for systems engineering to achieve a theoretical based set of functional specifications. This opportunity illustrates how human-built structures relate to the fractal similarities as entities that enables the opportunity to change its morphological existence, when social systems change within ecosystems adaption, biotic or abiotic, as a living organism (see Figure 4.13.).

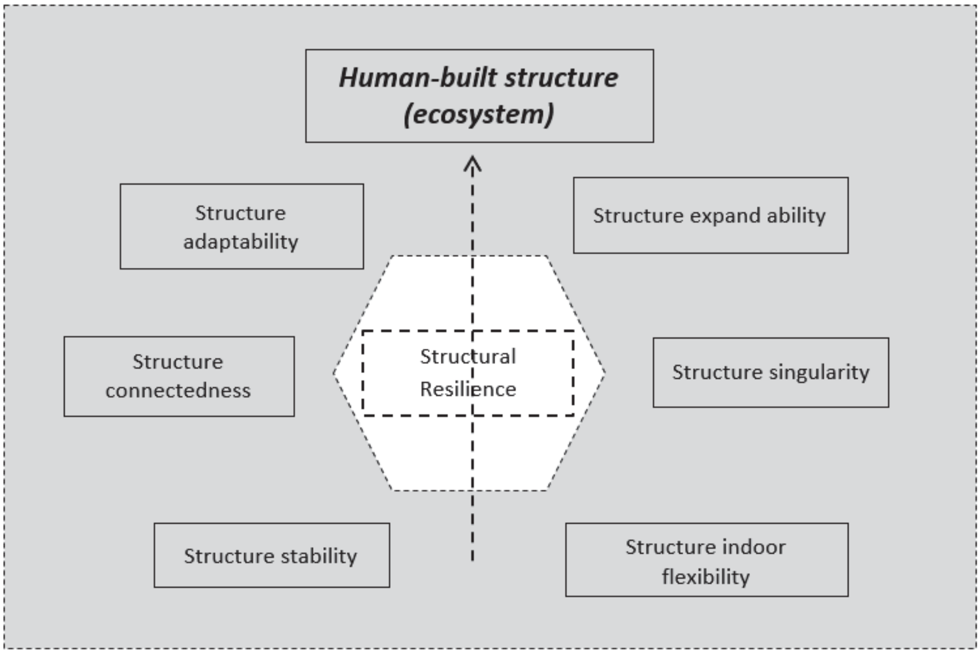

Figure 4.13. Human-built structure factors of building morphology.

When relating the human-built structure to all entities and underlying system factors it provides a coherence synthesis of mutual related factors for primary school building morphology. For example, internal changeable flexibility should be incorporated into the design for 25%, and the relationship with aesthetical factors here means a creative architectural synthesis that relates to the intra- and intersubjective social system experiences of variety, and (inter)objective materialization by a diversity of building elements. During the development of the design configuration (interior arrangement, floorplan, building) all multi-level scaled characteristics should also be involved such as how desks setting arrangement can change. This example illustrates a simplified method of how systems engineering approaches, such as by Building Information Modelling (BIM), might be improved to incorporate this current shortcoming systems. An overview of integrative functional specifications based on morphological factors is illustrated in Table 4.3. (see Table 4.3.)

Table 4.3. Overview of entities integrative specifications for human-built structure based morphological factors.

Weighting factor	Social system	Sustainable development	Environmental Concern	Ecosystem	Brief specifications	Morphological factors
40%	Certainty	Environmental	Scarcity	Resource	Functional	Structure
25%	Variety	Legal	Mono-culture	Diversity	Aesthetical	Flexibility
15%	Connection	Sociological	Disconnection	Coherence	Social	Connectedness
10%	Significance	Economic	Domination	Species	Financial	Singularity
6%	Contribution	Political	Withdrawal	Wealth	Sustainable	Adaptability
4%	Growth	Technological	Extinction	Extension	Technical	Expandability

These entities establish balance by weighting all factors. The results show that the stable system factors ‘structure’, ‘flexibility’ and ‘connectedness’ frames together are 80% of its functional specifications. More specific, for example considering the need for certainty, it fulfils 40% of the human need factors, and it relates 40% to the environmental factor, which relates for 40% to the environmental concern of scarcity, and increases the awareness of 40% to use real sustainable resources. Hence, in this example the calculated 40% of the factor relates to primary school building design that should contribute school management boards into the decision-making processes, with which the process can be finished by only some little dialogues and consensus. In the perspective of the presented research, school management boards should take into account thus integrated attention to the functional specifications of the building structure by analyzing the physical learning environmental shells characteristics. The summarized entities relate to the multi-level scales of (1) the social system related stakeholders needs (e.g. end-users, school management boards, society); (2) the whole-life building stages (e.g. design & construct; operation & maintenance; reuse & demolition); (3) the six spaces of intra- and intersubjective human system related mainly psychological and physiological experienced learning places (e.g. desks, classrooms, interior rooms, exterior, playground, surroundings; (4) the six places of (inter)objective ecosystem related mainly biological/ecological elements, materials and energy systems considering the ecosystem scales (e.g. bodily requirements, indoor, local, regional and global); and (5) its relationship with the multi-level scaled process stakeholders (e.g. disciplines from social sciences such as positive psychology, sociological ecology), and natural sciences (e.g. from ecology to organismic biology, to neurology, to cellular biology, and molecular biology studies). Two perspectives are considered to use: (1) a societal perspective of mainly outdoor directed to indoor, and (2) an end-user perspective of mainly indoor directed perspective to outdoor, as two defined distinguished approaches to use. Within this two perspectives a basic framework is established.

4.3. Results

The main result is the development of a theoretical framework that recognizes the underlying pattern of multi-level scaled similarity patterns, which are called entities. These social systems, ecosystems, and sustainable development related entities, and their mutual interrelationship with design brief sections, and the building morphology, determine theoretically the value of real sustainable primary school buildings by using all the described characteristics. These entities give room for define the primary school building design brief specifications and school building morphological requirements into more balanced than in current approaches occurs.

In order to state the practical application a step-plan is introduced by means of a questionnaire (see Table 4.4.). The elaborated Sustainability-Centered Guidelines for primary school building design (SCGs) are described into a table (see Table 4.5.). An illustrative example shows the practical usage of the developed conceptual framework of design morphology. To show the practical application an illustrative example clarifies conceptually the value for primary school design. The functional specifications are balanced by the entities, which action should be taken place into the decision-making stages of the process. The elaborated example shows three levels of scales (micro-meso-macro), which illustrates the systems thinking approach and recognizes the self-similarity pattern, in this case based on human system factors by the configuration of a (class)room, a school building, and a neighborhood arrangement. This fictive example illustrates how a societal perspective and its ratio percentages relates to each other by 40% certainty (Ce); 25% variety (Va); 15% connection (Con); 10% significance (Si); 6% contribution (Ctr); 4% growth (Gr). We note that different scales also can intervene substitutional which each other (between end-user, management board and societal perspective), and that different entities can intervene (between human needs factors and sustainable development factors), and different factors interrelate with each other by their polarities all multi-level scaled from individual workplaces to urban development and vice versa. For example, (1) a work desk; (2) a classroom; (3) the building layout/rooms; (4) the exterior of the building; (5) the surroundings/play-garden; and (6) the urban area/neighborhood. An illustrative example shows their mutual relationships (see Figure 4.14. and Table 4.6.). Another illustrative example shows how the two main polarity entities of 40% and 25%, and how the involved factors relate as a substantive translation of the guidelines from a societal perspective (see Table 4.7.).

Table 4.4. Questionnaire of Sustainability-Centered Guidelines for primary schools (SCGs).

Questionnaire of Sustainability-Centered Guidelines for primary schools (SCGs) (societal perspective)		
No.	**Wf. %**	**Entities and their factors**
1	40	**Certainty:** Why does it relate to the social system related factor of human need for certainty in balance with end-users, management board, and society? **Environmental:** Which materials and energy systems contribute to ecosystems' environmental factor considering the end-users bodily requirements, indoor quality, the school building, local, regional, and global scales effects, avoid scarcity, stimulate the use of renewable resources and ecosystem extension in relationship with the use of these building materials? **Functional:** Which knowledge is necessary to specify the functional specifications? **Structure:** How does the brief relates to the building morphological structure?
2	25	**Variety:** Why does it relate to the social system related factor of human need for variety in balance with end-users, management board, and society? **Legal:** Which materials and energy systems contribute to ecosystems' legal factor considering the end-users bodily requirements, indoor quality, the school building, local, regional, and global scales effects, avoid of mono-culture, stimulate the use of renewable resources and ecosystem (bio)diversity in relationship with the use of these building materials? **Aesthetical:** Which knowledge is necessary to specify the aesthetical specifications? **Flexibility:** How does the brief relates to building morphological flexibility?
3	15	**Connection:** Why does it relate to the social system related factor of human need for connection in balance with end-users, management board, and society? **Sociological:** Which materials and energy systems contribute to ecosystems' sociological factor considering the end-users bodily requirements, indoor quality, the school building, local, regional, and global scales effects, avoid disconnection, stimulate the use of renewable resources and ecosystem coherence in relationship with the use of these building materials?

		Social: Which knowledge is necessary to specify the social, educational vision, identity specifications? **Connectedness:** How does the brief relates to the building morphological connections?
4	10	**Significance:** Why does it relate to the social system related factor of human need for significance in balance with end-users, management board, and society? **Economic:** Which materials and energy systems contribute to ecosystems' significance factor considering the end-users bodily requirements, indoor quality, the school building, local, regional, and global scales effects and avoid domination, stimulate the use of renewable resources and ecosystem species in relationship with the use of these building materials? **Financial:** Which knowledge is necessary to specify factor 1 to the financial specifications? **Singularity:** How does the brief relates to the building morphological singularity?
5	6	**Contribution:** Why does it relate to the social system related factor of human need for contribution in balance with end-users, management board, and society? **Political:** Which materials and energy systems contribute to ecosystems' political factor considering the end-users bodily requirements, indoor quality, the school building, local, regional, and global scales effects, and avoid withdrawal, stimulate the use of renewable resources and ecosystem wealth in relationship with the use of these building materials? **Sustainability:** Which knowledge is necessary to specify the 'sustainability' ambition specifications? **Adaptability:** How does the brief relates to the building morphological adaptability?
6	4	**Growth:** Why does it relate to the social system related factor of human need for growth in balance with end-users, management board, and society? **Technological:** Which materials and energy systems contribute to ecosystems' growth factor considering the end-users bodily requirements, indoor quality, the school building, local, regional, and global scales effects, avoid extinction, stimulate the use of renewable resources and ecosystem extension in relationship with the use of these building materials? **Technical:** Which knowledge is necessary to specify the technological specifications? **Expandability:** How does the brief relates to the building morphological expandability?

Table 4.5. The Sustainability-Centered Guidelines for primary school building design (SCGs).

1	Consider the different end-users' and societal physical learning shell perspectives of intra- and intersubjective experiences by human needs (spaces) and intra- and inter-objective factors of sustainability requirements (places) within the dynamic of the conditional circumstances and characteristics, such as polarities, resilience, time/stages and the ratios required to find a balance, and to relate them to adjusted discipline domains.
2	Consider the pattern similarity entity to balance 40% of the value for certainty and environmental influences and to establish the 40% functional specifications for functionality in the brief and during the design iteration stages for multi-level building structure.
3	Consider the pattern similarity entity to balance 25% of the value for variation and legality influences and to establish the 25% functional specifications for aesthetical and creative specifications in the brief and during the design iteration stages for multi-level building flexibility.
4	Consider the pattern similarity entity to balance 15% of the value for connection and sociological-cultural identity influences and to establish the 15% functional specifications for social specification in the brief and during the design iteration stages for multi-level building association..
5	Consider the pattern similarity entity to balance 10% of the value for significance and economic influences and to establish the 10% for financial specifications in the brief and during the design iteration stages for multi-level building singularity.

6	Consider the pattern similarity entity to balance 6% of the value for contribution and political influences and to establish the 6% for durable specifications in the brief and during the design iteration stages for multi-level building adaptability.
7	Consider the pattern similarity entity to balance 4% of the value for growth and technological adjustments and to establish the 4% for extension specifications in the brief and during the design iteration stages for multi-level building expandability.

Illustrative example (1)

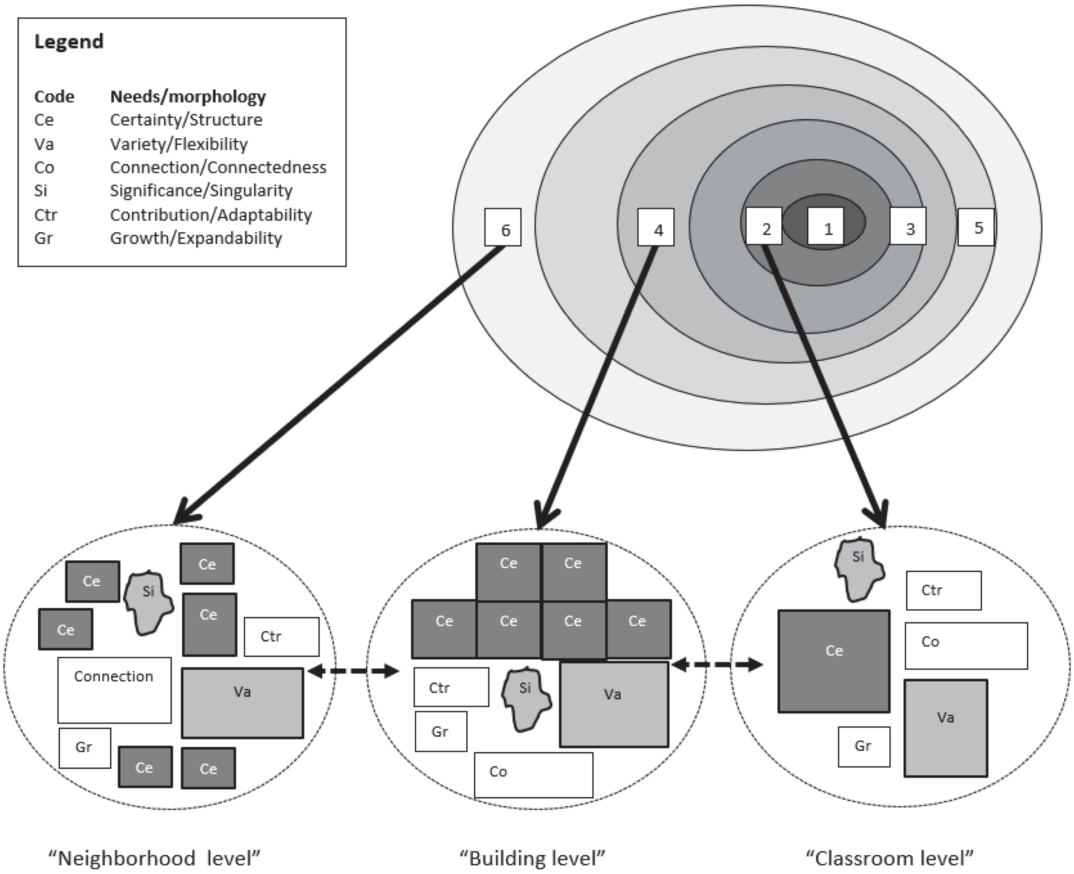

Figure 4.14. Example of human needs weighted morphological multi-level scaled relationship.

Table 4.6. Example of entities and level scaled relationship.

Entity	Levels		
Needs/morphology	**Neighborhood**	**Building**	**Classroom**
Certainty/Structure	Urban structured building block arrangements	Clear building structure	Main learning place area for the whole group
Variety/Flexibility	Variety of building design and arrangement setting differences	Variety of building blocks and their appearances	Different easy to change workplace arrangement
Connection/Connectedness	Relationship between the different buildings	Connection of different building blocks, and scale relationship with surroundings (e.g. playground)	Connection of different places for different functions into the (class)room to collaborate, or to connect with others rooms

Significance/Singularity	Special building appearances and arrangement of buildings	Special building features to express for example the social identity or culture	Special place for special circumstances
Contribution/Adaptability	Urban area and new building blocks adaptability	Adapt external building changes (e.g. to reduce energy waste)	Adapt new physical learning features/ methods (e.g. use of devices)
Growth/Expandability	Urban development and building blocks expand	Expand the building functionality	Expand the classroom functionality (e.g. incorporate new technology)

Illustrative example (2)

Table 4.7. Conceptual functional specification example for two main entities.

Sustainability-Centered Guidelines for primary schools (SCGs)		
No.	%	Guideline prescription of entities from a societal perspective
1	40	From a societal perspective the first step is to relate the first entity to the configuration of arrangement of the physical shells: exterior, playground, neighborhood (desks, classrooms, interior should be considered mainly from an end-user perspective): Certainty: the blocks are arranged from an intra- and intersubjective perspective of 40% to be experienced as a stable structure, which generates the feeling of security, safety et cetera. Environmental: 40% of the building materials and energy system resources should not cause scarcity, but stimulate local or regional extension of new ecosystems. The used materials (or products) do not affect the health (biophysical relationship). Used materials are wood, straw, et cetera in general called ecological materials. Ecological, biological knowledge is needed to be sure that used materials are not affecting the environments (bodily, indoor, local, regional, global). Functional: 40% of the building should be designed as pure functional and stimulates to use as few as possible materials and energy. Knowledge of educational processes/vision is needed. Structure: 40% of the building design structure is stable by its own materials and energy systems.
2	25	From a societal perspective the second step is to balance the polarity mechanism with the social system need for certainty et cetera. Variety: the blocks are arranged from an intra- and intersubjective of 25% to be experienced as a unexpected, challenging, frequently changing setting (e.g. indoor walls arrangement), which generates the feeling of excitements and positive tensions et cetera. Legal: 25% should be reserved all over for extra ambitions (e.g. this fits to the focus on desired situation instead of to focus on minimal rules). Current approaches of governmental and local authorities legislation are mainly based on minimal rules. Aesthetical: 25% should be found into the creative design solutions to balance the arrangements optimally and maximize the variations. Flexibility: 25% of the morphology should be flexible to change (e.g. the building blocks can be removed easily to reuse elsewhere)

4.4. Discussion

The used method recognizes the similarity patterns derived from human needs, sustainable development factors, and ecosystem concerns and services. This approach connects all different multi-levels of scales by social interventions on ecosystems. Multi-level scaled social interventions affect per definition multi-level scaled ecosystems and vice versa, due to their interrelationship. Subsequently human needs relates also to the translation of the needs to client briefs and building morphology. The multi-levels of scales of interventions are from this perspective unbalanced in current exceeded design system. The sustainable performance of school building design in current approaches is affected by a complex of especially process related problems, with which current steady stated approaches are more related to the product than to the process. Metric data systems and assessment tools constrain the design approaches that lack the dynamics of changes and social interactions. Also sustainable development factors are not balanced in current methods, and lack the polarities, resilience and impacts. Current systems are, without be wanting too pretentious, incomplete for application in current school building construction design approaches, simply due the fact that these systems are functioning too statically. The dynamic balance is a most important factor to discuss whether the presented idea of stating the universal human needs as a self-similarity pattern language for considering ecosystems interventions, and derive the entities, whether this pattern can be used consistently for defining the resilience of sustainable development, and by using the golden mean as a weighting system.

A number of most exciting studies, such as stated by Xu, Marinova & Guo [26] that emphasise the ecological aspects of resilience, but exclude the human activities, are also researched, whether we could find support for our own hypothesis. Although different methods use different principles, indeed all studies lack an integrative system of social and ecosystems dynamics, and their qualitative and quantitative relationships. For example, the Framework for Strategic Sustainable Development (FSSD), also known as 'The Natural Step' developed by Robèrt [53], defines a systems thinking based method, but which lacks the integration of combine ecosystems and social systems. Missimer [54] researched the possibility of a systemic and generic approach to social sustainability, also known Framework for Strategic Sustainable Development (FSSD), and they proposes a way forward to make the social dimension on the FSSD more cohesive as well as operational, which thus point into the direction of searching for connection between the human systems and ecosystems as we assume. Natural Capitalism [55] uses recognizable sociological, economic, technological and environmental factors, but these four factors remain positioned as separated independent entities. However, Baden & Zaffos, who reviewed the book Natural Capitalism [55], identified growing agreements that economic prosperity and environmental quality are complementary aspects of progress [56]. The Cradle to Cradle system, developed by Mc Braungart & McDonough [57], uses biological and technological circles, which does not involve integration of human development into the system. Clements-Croome states that Braungart & McDonough believe *form follows evolution* rather than *function*, but in reality both apply [52]. Hence, Clements-Croome [52] in fact identifies the morphological relationship as a polarity between upwards directed need for evolution (growth) and downwards directed need for functionality (certainty). From this point of view other polarity morphological links exist by stating that form follow also the inwards directed need for an individual end-user, such as a pupil, and outwards directed need for connection such as peer groups, a teacher, parents, the local community, society. Perhaps it is better to state *form follows polarities (or possibilities).* The Panarchy theory, see [43], [44], takes into account double, apparently paradox, dualistic characteristics, and uses thus the polarity mechanism of complex systems. Although the system describes the complexity of balancing the antagonistic strive for stability and instability of changes, this integrative framework which connects ecological, economic, and social models together, and considering their stable and instable system interactions, and its multi-level scales, it lacks an operational system to use for practical application such as for school building design. Harzog states in his 'Governance in the network Age', that the term Panarchy emerges at the intersection of three core concepts: (1) ecology and complex systems, (2) technology, and (3) politics, see [58], which show the dynamic relationship between stable and unstable systems, and the vulnerability of ecosystems resilience. Baudains et al. state that buildings are complex systems and systems engineering and complex modelling can help address failures of existing practices during the process and during the whole life cycle of the building which might be achieved through further research of the complex components of both physical subsystems and building users [59]. The presented article might provide into this paradigm.

Using the golden mean as a calculated weighting system to regulate the complexity of interrelated factors for practical application needs more introduction and accompaniment. There are some benchmarks that state the quantitatively similarity of the patterns. For example, the calculated 10% for the economic part is rather equal to the Brundtland Commission calculated 5-10% space for economic growth. The main factors of stability form together 80%, and the unstable factors 20%, which is a rule of common sense. The reduction of the complexity to define Sustainability-Centred Guidelines for primary schools (SCGs) in this holistic approach, to consider the bigger picture and underlying patterns by connecting social and ecosystems to human-built structures, needs a lot of generalisation and practical reasoning to become credible. It demands more theoretical knowledge of different fields of disciplines how to connect to current primary school design processes. Although the theoretical framework should be tested and proven for practical application, students already experiment with it during their final thesis. Their preliminarily experiences are positive considering the translation of the human needs, sustainable development, ecological factors, and building morphology ratios for weighting the balance into their building designs.

4.5. Conclusion

The aim was to develop a theoretical framework to find ground for recognizing the whole picture and underlying code and the relationships to untangle the complexity of interwoven primary school building design failures of existing practices during the process and during the whole life cycle of the buildings, and to deliver sustainability-centred guidelines for real sustainable primary schools (SCGs). To untangle the complexity of interwoven failures a theoretical framework is elaborated that incorporates qualitative and quantitative factors, and uses social system and ecosystem linked similarity patterns to define a stable set of entities to frame the decision-making processes. The development of this approach lead to an integrative synthesis of social system and ecosystems based patterns of sustainable development relationship, and its similarities patterns with client briefs and primary school building morphology. The method involves a number of elaborated characteristics and considered multi-level scales that generate new guidelines for practical application. The identification of recognized patterns is a theoretical approach that needs to be tested for practical application.

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Chapter 5
AEC INDUSTRY INTERESTS

Adapting Dutch Primary School Building Designs and Processes using human needs based hypotheses as a polarity pattern framework for integrating different interest

ABSTRACT

The Dutch Architecture, Engineering and Construction (AEC) industry struggles with creating healthy, sustainable and durable learning environments for primary school education that meet the needs of society, local communities, end-users and individual participants involved. Currently, an important aim of the AEC industries is to improve its processes in order to deal with the complexity of today's design assignments. The AEC industry intents to innovate by focusing on three themes of interest clusters: (1) to position end-users more central in the design and development process, (2) to transform its linear process towards materials into a circular one and towards the use of renewable energy resources, and (3) to make buildings more flexible and adaptable. To realise the aim towards process improvement, the AEC industry mainly uses rational, objective and technological methods, neglecting human factors at play. In order to deal with these human factors and complexity of design assignments, a multi-level approach of design and development is applied, which follows the rational to bring more balance between the interests by addressing the underlying patterns. This approach offers the possibility to include additional requirements and future technological developments, to accommodate changes of insights in different knowledge domains. This approach results in a framework which can be used for balancing new school building design and processes. It facilitates learning, even on aspects that are usually not included in building projects. The framework is validated in a series of expert meetings. And finally, this chapter derives practical process-centred guidelines for school building design (PCGs).

Additional information chapter 5	
Authors	R.de Vrieze[a], M.A.R. Oostra[b]
Being prepared for submission	

[a] Hanze University of Applied Sciences – Research Centre for Built Environment NoorderRuimte, Van Doornveste; Zernikelaan 11, 9747 AS Groningen, The Netherlands.
[b] Hanze University of Applied Sciences – Research Centre for Built Environment NoorderRuimte, Van Doornveste; Zernikelaan 11, 9747 AS Groningen, The Netherlands.
University of Applied Research Utrecht, The Netherlands - Research Centre for Healthy & Sustainable Living; Padualaan 99, Utrecht, 3584 CH, The Netherlands

5.1. Introduction

In the Netherlands one out of eight school buildings is so much outdated that major renovation or demolition and replacement is urgent (RVO 2014). About twenty-five percent might be sufficiently functional, but needs maintenance or improvement (RVO 2014). A teacher satisfaction poll shows an average score of 5.7 out of 10 considering Dutch primary school-buildings (AR 2016). Remarkable is that recently new built school buildings perform not significantly better than outdated schools according to end-users. Netherlands governmental Enterprise Agency RVO identified a large number of product and process related problems in recently built schools (RVO 2014). Problems and other negative effects related to processes include, for example, distrust between client and business stakeholders, dissatisfied performance of school building quality and sustainability, and a fragmented Architecture, Engineering and Construction (AEC) industry (RVO 2014). The complexity of school building design, as a result of different stakeholder interests and relationships, is difficult to deal with for AEC industry to establish sustainable and healthy school buildings. Current AEC industry ignores the call for integrated school-building design, it fails to anticipate current educational visions, and is not able to translate educational visions into material spaces (Mumovic 2015). Experts of school building design, such as prof. Heppell, hope that 'the emerging paradigm will translate into improved learning spaces and will influence future architectural design' (21st Century 2013). School building design visions are changing fast, for example, due to the introduction of school design concepts without classrooms, personalized learning, blended learning, and flexible learning environments (e.g. 21st Century 2018). Technology and the move to personalizing learning, collaborative work and projects are changing classrooms already (e.g. Bray & McClaskey 2018; Penoyre & Prasad 2018). Educational institutions acknowledge these changes (e.g. OECD 2015; OECD 2016a; OECD 2016b; Education-2025 2015; Wetering 2016; Johnson, Adams & Cummins 2012). Ignoring these changes might result in disappointing indoor performance and low quality plan lay-outs. The Dutch architectural organisation BNA conducted their own school-building design failures research as an assessment of the many complaints of end-users and school boards, but did not have published all their internal found results publicly (BNA 2011). According to architect Herman Herzberger (2008) the overall design of Dutch primary school-buildings has remained unchanged for many decades, but the primary educational process is changed considerably (Herzberger 2008). Herzberger (2008) also states that school-building designers never have improved their school designs, and they have been approached uncritically for too long (Herzberger 2008). The AEC industry wants to renew and improve the current failing system for school building, but a method that incorporates more balance between all different interests lacks. On the one hand interests differ between society, local communities, generic end-users, and individual end-users of the buildings. On the other hand the AEC industry actors acknowledge the need for collaborating less fragmentated and sharing more information, as well as improving productivity and quality into the sector to reduce the construction process and failure costs in practice (TUD/CPI 2014). To renew the construction sector, innovation theories are used, such as the theory of diffusion of innovations developed by Everett Rogers (2003), but for the AEC industry it did not bring the improvements expected (e.g. Donker-Blacha 2017). Productivity improvements of the AEC industry are poor compared to other sectors (Barbosa et al. 2017). However, Product-Market Combinations in the construction industry (PMCs), Open Building Manufacturing

(OBM), Lean Construction, and Offsite Manufacturing Construction (OMC), show how construction industry is changing towards mass-customization and offsite production (Kazi, Hannus, & Boudjabeur 2009). Zaal (2007/2009) states that a cause of the current situation is the persistent role of specific stakeholders, especially real-estate developers, architects, and contractors who constrain the construction process too much in the early stages. On the one hand this latter situation might be a part of how improvements are obstructed by conventional systems and delaying changes in school building design methods. On the other hand a too industrial approach for school building might not be desired, but should challenge end-users of school buildings with modern design and preferences for using ecological materials and natural environments.
A structural improvement is desired of indoor climate quality, energy efficiency, and flexibility among other things, as recently published by a new program of the AEC industry for school-buildings (Bouwagenda 2017). The program involves different plans to achieve these structural improvements. The aims of this program should be integrated in the innovation themes of the Dutch Action-team Innovation, which is part of the Action Agenda Building construction ‘de Actieagenda Bouw’ to generate innovations in the AEC industry (TUD/CPI 2014). This Action-team highlighted three focus areas for innovation (TUD/CPI 2014): (1) to position end-users more central in the design and development process, (2) to use circular approaches for material applications and renewable energy, and (3) to make buildings more adaptable for future changes (TUD/CPI 2014). Although these innovation themes suggest improvements it does not incorporate an integrated approach. The program seems to lack a method to structure and balance all different interests. These themes of interests include end-user interests, circular approaches of material and energy from a sustainable development perspective, as well as a method how to deal with future perspectives of changing educational needs, but exclude AEC industry interests. The first two themes fit to the developed framework presented in chapters 2, 3, and 4. For AEC industry interests and to adapt future changes a new framework is developed by distinguishing four steps: (1) explaining the construction of the previous developed framework’s fundaments, (2) explaining previous analysed interests clusters, (3) synthesize them with AEC industry interests, and (4) future changes.

Aim of the research presented is to anticipate Dutch primary school design for future changes while dealing with its complexity caused by all different interests. Based on the analysis of the problems and challenges the hypothesis is that the capacity of school building design processes to deal with complexity can be improved by establishing a framework that includes and balances all interests. This framework consists of three clusters: (1) sustainable development, environmental interest, (2) psychological, social & educational interests, and (3) the interests of the parties from the AEC industry and its institutions, which includes the supply chain and their mutual relationships.

The research question therefore is: can a framework be realized for the school building design process to understand and to deal with the complexity in school building design, based on the understanding of the interaction patterns between interests?

As a start an inventory of the problems in school building design was made, as well as an developed instrument that identifies already AEC industry involved stakeholder interests and how these interests relate to the design problems (Vrieze & Moll 2015). Not only the interests patterns of the school building design process were analysed to understand the origin of the physical school building problems and its complexity, also a start was made to construct a coherent framework on how these interests interrelate (Vrieze & Moll 2018, 2017).

The research of this chapter builds on the previous chapters 2, 3 and 4 (articles 1, 2, and 3), wherein the polarity pattern framework is explained. In the earlier chapters this polarity patterns approach is used to establish a framework based on the hypothesis of the psychological, sociological and educational interests cluster and the environmental interests cluster. In this presented chapter the interests cluster of AEC industry and their interrelations will be combined with these previous frameworks based on the other two developed interests clusters into a integrated framework: the polarity pattern framework, in which the interests around school building design are balanced and multi-level scaled connected. In order to construct this framework an analysis of the interests and mutual related patterns of the AEC industry interests is made for school building design and processes. This chapter follows the rational similar to the previous chapters that by understanding and dealing with the underlying constellation of interests clusters, it might become possible to deal with the complexity of these in design assignments and AEC industry, while it enables to balance the different aspects and interactions between interests and interrelations that follow consistent patterns. This chapter will generate finally Process-Centred Guidelines (PCGs) for practical application. The consistency of the developed polarity pattern framework has been validated by a series of bottom-up (e.g. end-users), middle up-down (e.g. school management boards) and top-down (e.g. community, society) discussions with experts from AEC industry (e.g. architects, construction engineers) as well as from social sciences (e.g. psychologists) in monthly meetings per group, and five relevant tests. A description of the outcomes of these meetings is provided. The chapter ends with a discussion and summary & conclusion section.

5.2. Synthesis of the theoretical framework

The Triple Bottom Line (TBL), first coined by Elkington (1998) is used as a point of departure for a synthesis of the theoretical framework. The Triple Bottom Line (TBL) aims at a responsible balance to be achieved between social, environmental, and economic interests, also known as the ‘People-Planet-Profit’ triangle framework. The TBL framework connects the sociological ‘People’ subsystems to the environmental ‘Planet’ subsystems, and to the economic ‘Profit’ subsystem. The term ‘Profit’ was replaced during the UN-top in 2002 at Johannesburg with the term ‘Prosperity’. Some researchers use also variants of the 3 P’s, for example, Product, Process, and People (Ning Gu & London 2010). The problem is that the terms Profit and Prosperity both assume realizing balance together with the terms People and Planet. In the previous chapter an unbalance is identified between these three terms of People-Planet-Profit, and besides that, also three terms lack. When the three Elkington related terms are replaced by Sociological, Environmental, and Economic, obviously the terms Legal, Political and Technological lack and should be added. The six terms together are known as the six ‘PESTEL’ factors of sustainable development used in environmental studies. In the previous chapter it is suggested how a balance between the Environmental (Planet), Sociological (People), and Legality factors is considered as main important factor for stabilizing the system (robust). It also suggests how a stable system of school building is influenced by the destabilizing more dynamic system factors, such as financial, political, and technical changes which affect Dutch Primary school building and AEC industry. Finally, it is suggested in previous chapter 4 that Environmental and Sociological factors are influencing the design products (materials/energy) and the other factors are influencing the process.

To realize a synthesis of a new theoretical framework, the AEC industry interests and adaptivity for future changes should be incorporated. The new theoretical framework should therefore combine the results of both previous chapters 2, 3 and 4 of sociological and environmental interests clusters, with the AEC industry interests clusters. Because the economic and technical interest of this cluster shows a mismatch with People and Planet, to offer balance from a sustainable development perspective, the other 'PESTEL' factors should be added. If we combine the product and process related factors with the sustainable development factors (see previous chapter 4) especially the factor Legal (e.g. legislation, ambitions) should be considered as a factor that offers resilience and adaptivity in the system between Planet and People (Environmental and sociological factors). Therefore it is suggested in the presented chapter to replace the terms 'Profit' and 'Prosperity' with the term 'Possibility'. The term 'Possibility' can represent system resilience and adaptivity, which means quest for improvement between on the one hand the social (People) and on the other hand environmental (Planet) possibilities. These 'People', 'Planet', and 'Possibility' dimensions should therefore in this hypothesis form together a resilient and adaptive system. These three-folded system of stabilizing factors of Planet, People, Possibilities in this chapter is called 'Opportunities'.

At the same time we should not close our eyes for the fast global changes. Economic, political and technological trends and unknown, or even unknowable future changes that influence the 'Opportunities' system stability. Technological innovations, changing politics, and economic renewal, influence the way the People-Planet-Possibility system is composed and affect school building design and processes, and the AEC industry. The three-folded system of destabilizing factors of political, economic, and technological changes in this chapter is called 'Probabilities'.

The hypothesis is that this framework with its six PESTEL factors, can be associated with self-similarity patterns and a polar mechanism as recognizable in several existing methods and theories to connect this kind of fractal (see chapter 2,3 and 4) now also to the world of design and construction. For example, biophilic design for school building materialization (see section 5.3.4.2), and Belbin types of roles tests (see section 5.3.3.2) for school building processes seems to share similar underlying patterns.

When these three stabilizing and robust 'Opportunity factors' and three destabilizing more dynamic 'Probability' factors work like a polar mechanism, and are related to the AEC industry themes of the Dutch Action-team Innovation (TUD/CPI 2014), they seem to share considerable associative patterns of self-similarity: (1) to position end-users more central in the design and development process actually can be associated with sociological factors (People); (2) to use circular approaches for material applications and renewable energy can be associated with environmental factors (Planet), and (3) to make buildings more adaptable for future changes can be associated with the term Possibilities. Now the three clusters of sociological interests, environmental interest and AEC industry interest (technical and economic) can be synthesized.

5.3. Synthesis steps

The synthesis aims to synthesize the AEC industry interests cluster with the human needs and sustainable development interests clusters. Therefore it is needed to explain the construction of the developed framework's fundament, and its relationship with the environmental and sociological interests. With the use of the stabilizing 'Opportunities' factors and destabilizing 'Probabilities' factors, their polar relationship is recognizable. The technological, economic and political factors, belonging to 'Probabilities' covers a main part of the AEC industry cluster interests. This way the new theoretical framework will be developed and presented in a number of steps, to gradually construct a framework for the design process of sustainable school buildings built on associative patterns of self-similarity. The steps, that represent the interests clusters influencing the design process will be analysed, are:

1. The construction of the framework's fundaments, based on environmental requirements. All the aspects of environmental requirements are summarized and balanced under the umbrella term: Planet.
2. Adding the people perspective by including psychological, sociological and educational interests, including the interests of its institutional sector (e.g. Dutch council for primary education: POraad). These interests aspects are balanced under the term: People.
3. Adding the interests of the AEC industry and the influences of engineering, realisation, operation and maintenance processes. These interests, although political influences are excluded here, are summarized and balanced by the term: Probabilities
4. And finally, as a last step, the 'Opportunity' term completes the three-folded 'Possibilities' factors by system resilience and adaptivity. By looking at 'Opportunities', 'Probabilities' and future changes with the aim to address the three innovations themes within these framework the next steps are conducted: (1) to position end-users more central in the design and development process, (2) to use circular approaches for material applications and renewable energy, and (3) to make buildings more adaptable for future changes.

5.3.1. Step 1: Planet, balancing environmental requirements

If we are serious in changing current society into a sustainable one, we should start from an environmental perspective. Earths' ecosystem should be considered as the only one profound basis for that. This might as well be our starting point in the synthesis for sustainable school building design. The part of constructing the basis of the synthesis can be found in more detail in the chapter 'An analytical approach towards sustainability-centered guidelines for Dutch primary school building design' (Vrieze & Moll 2017). An important conclusion is that sustainability means that the interests of people, planet and possibility should be in balance. At the moment the system is out of balance, which is also visible in current school building design, destabilizing factors, such as economic, political and technological factors, seems to dominate current school building design. To unravel current unbalance in school building design, the two main contradictory sub-systems of 'Opportunities' (people, planet, possibilities) and 'Probabilities' (economic, political, and technological, which are all sustainable development factors, are further distinguished into two polarities of interests clusters that should be in balance continue: the *mutual* and *hierarchical* interests.

The mutual interests are defined by sociological interests, such as educational and social interests on the one hand, and the economic interests, such as AEC involved stakeholders interests on the other hand. Here the mutual polarity can be recognized. The hierarchical interests polarity are mainly defined by environmental interests on the one hand, and the technological interest on the other hand. From a sustainable development perspective a stable balanced system is, as mentioned before, defined by the stable factors environmental, legal, and sociological, and an unstable system with the factors economic, political, and technological (Vrieze & Moll 2017). This hypothesis of polar relationship is described more comprehensively in previous chapters. Also described is how these mutual and hierarchical polar interests are related to a balanced system (see Table 5.1). To elaborate the synthesis with the AEC industry interests, a relationship is made between sustainable development and human needs factors. The integration of human needs and similarity patterns will be described further in step 2.

Table 5.1. The relation of different sustainable development factors (Vrieze & Moll 2017).

Polarity	Mutual/Heteronomous polarity entities:	Mutual/Autonomous polarity entities:
Hierarchical/Instable (dynamic) system) polarity entities:	Political	Technological
	-	Economic
Hierarchical Stable (robust system) polarity entities:	Sociological	-
	Environmental	Legal

5.3.2. Step 2: People central: integration of psychological, sociological & educational interests

In order to get an overview of the psychological sociological and educational interests, a look at the following aspects is necessary: personal needs and personal developments, team dynamics and complex educational context.

5.3.2.1. Personal needs and personal developments

People have a fascinating myriad of needs. These can be decomposed into a system of six needs by using the polarities, stable vs. unstable and autonomous vs. heteronomous factors. On the one hand the need for certainty, connection, and contribution, which are heteronomous, and on the other hand variety, significance, and growth, which are autonomous interests.(Vrieze & Moll 2015, 2018). In previous chapters a format is developed that shows the used rational of associative patterns of self-similarity between human needs and sustainable development factors, as well as association with project briefs and morphologic factors used in building construction (Vrieze & Moll 2017). The table in this section shows the self-similarity pattern. This associative way of thinking needs generic terms, such as all the specific domain related factors are mentioned 'entities' (see Table 5.2.).

Table 5.2. The relation of different human needs factors (Vrieze & Moll 2018, 2017, 2015).

Polarity	**Mutual/Heteronomous polarity entities:**	**Mutual/Autonomous polarity entities:**
Hierarchical/Instable (dynamic system) polarity entities:	Contribution	Growth
	-	Significance
Hierarchical/Stable (robust system) polarity entities:	Connection	-
	Certainty	Variety

The needs for certainty, variety and social connection are defined as stable factors, and the needs for significance, contribution and growth as unstable factors (Vrieze & Moll 2017). All six human needs can be associated with the six sustainable development 'PESTEL' factors. The stable (environmental, legal, and sociological) system, and unstable (economic, political and technological) system polarities. If new political policy is influencing the robust system by destabilizing dynamic factors, for example, the introduction of inclusive education, the system is not be able to incorporate such changes easily.

An illustrative example shows how the synthesis of cluster interests of human needs and sustainable development interests relate to each other and integrate. The Human Scale Development matrix of Max-Neef (1991) is therefore analysed. The self-similarity patterns can be recognized with using Table 5.1 and Table 5.2. (see Table 5.3.).

Table 5.3. Factors of Max-Neef (1991) Human Scale Development matrix structured in the two dichotomies of stable vs unstable and heteronomous vs autonomous.

Polarity	Mutual/heteronomous development scales:	Mutual/autonomous development scales:
Hierarchical/instable development scales:	Co-operate/plan, take-care of, help (doing) and political/contribution	Educational factors (having) and technological/growth
	-	self-esteem (being) and economic/significance
Hierarchical/stable development scales:	Sense of belonging (being) and sociological/connection	-
	Living environment (interacting) and environmental/certainty	Equal rights and choose (having/doing) and legal/variety

To understand these underlying patterns for school building design, theoretical information from social studies can contribute. Important is to note that human needs are considered here as a generic universal system, sharing similarities. At the same time though factors that cause individual satisfaction, should not be seen as universal, since they emerge from the subjective perception of each individual (Doyal & Gough 1991). In the following section we will pay attention to individual needs of team members in the school building process.

5.3.2.2. Influence of team dynamics

Since a lot of people work on school building design plans and their realization, it is important to have an eye for the interaction between people involved. Therefore a closer look at the school building design team is necessary. A large number of tools are developed that take individual differences into account within teams in order to improve the communication in teams. Van den Berg (2009) researched the underlying behavioural patterns of stakeholders in teams, by identifying power-positions, mechanisms of exclusion, trust questions, and communication problems, which together determine the effectiveness of a team (Berg 2009). Van den Berg (2009) described that team dynamics are rarely part of the conscious experience. They mainly are governed by behaviour based on self-interest, feelings of fear and loss, resulting in relationship issues (Berg 2009). Sigmund Freud already claimed that most of our behaviour is based on emotions instead of rational thoughts. Alexander, Brown & Joshua (2010) state that thinking-failures occur, because of overwhelming complexity or decision-making under pressure. It is the question whether non-rational behaviour is a result of this, or just a way to improve individual satisfaction (Alexander, Brown & Joshua 2010). Social behaviour involves a lot of thinking based on a non-logical, mainly subjective social reality and people's own experiences. Reality is not experienced in an objective manner, because of individual constructs (Bless, Fiedler, & Strack 2004). This phenomenon leads to a distorted view, non-rational biases, and wrong interpretations (e.g. Kahneman 2002; Ariely 2008; Baron 2007). Conditioned thinking patterns, evolutionary heuristics and constrained human brain capacity systems obstruct rational thinking (Haselton, Nettle, & Andrews 2005). Individual subjective factors can influence the objective rational views in teams. The use of the polarity pattern system might help to be aware of unwanted behaviour.

The mutual related interests are defined in this chapter by the stakeholders with societal educational interests (e.g. between individual end-users, end-user groups, school management board, and local community) on the one hand, and the technical and economic related interests of AEC industry on the other hand. From a sustainable development perspective the definition of a mutual balance system is more complicated, because of its interwoven dependency of autonomous and heteronomous interests. The different levels of sociological stakeholder interests (e.g. local community, end-users) are connected, but economic stakeholders also relate to these scales in multiple ways. Here a polar relationship can be recognized between economic and rather autonomous interests on the one hand, and societal, heteronomous interests on the other hand. From a sociological point of view, economic rationalism strongly resembles egoism (Tellegen & Wolsink 1992). Here a relationship with autonomous interests can be recognized by terms such as egoism. De Ridder (2011) also recognizes this distinction between on the one hand the sociological system of interests with its regards for aesthetics, capacity, size, flexibility, sustainability, and on the other hand the economic system, with a focus on investment costs, operating costs and maintenance costs (Ridder 2011).

5.3.2.3. Complex educational context

The interests of the primary education conglomeration can be decomposed in five scales, that mutually influences each other: (1) society; (2) the local community (e.g. municipality/council, educational institutes); (3) school management board; and (4) end-users groups (e.g. pupils, teachers, pedagogues), and (5) individual end-users. The client position relates in this case best to the school management board, although municipalities still are ultimately responsible for new school building investments. However, increasingly they mandate school management boards to take over the client role (AR 2016). As a result the school management board is positioned in the middle, a middle up-down position (Oostra 2013) between end-users and local community, managing and balancing the design and construction phases, taking into account the operation and maintenance costs and future changes, and last but not least the ambitions of the municipality. A proper decomposition of the complex system of needs (which includes educational stakeholders) can be made by a disentanglement of bottom-up and top-down interests. Bottom-up interests relate to individual and generic end-user interests, and can be especially related to building indoor spaces (e.g. classrooms, playgrounds). These interests consist of intrasubjective (individual) and intersubjective (generic) experiences of the spaces (e.g. functional, cognitive and sensory). Top-down interests are mainly representing societal gains and needs, and local community interests. They relate especially to outdoor spaces (e.g. school districts, neighbourhoods) and to objective factors (e.g. education vision and school design quality). The interior design might thus be more related to the bottom-up interests instead of top-down interests, whilst exterior design might be more related to the local community and society. The middle-up down approach (Oostra 2013) helps to align the social (educational) process requirements with the material design. A top-down approach of school building design especially consist of objective generic requirements, whilst a bottom up approach especially seems to consist of subjective individual requirements. For example, an objective physical *place* for pupils to read a book is also subjectively a *space* for reading. Both, subjective and objective design quality indicators (DQIs) are also described by the Dutch foundation Ruimte OK to support school-management boards to define their program of requirements (Ruimte-OK 2014/2017). Habraken (2000) also distinguishes between places and spaces. Brand (1994) has always been critical of the modernist approach to architecture and rejects the idea that a single person or group designs a building for others to use, and asserts that the best buildings are made using low-cost, standard designs that people are familiar with, and are easy to modify. Brand (1994) defines different objective 'layers': stuff (e.g desks), services (e.g. electrical wiring, heating, ventilation); and space plan (e.g. interior lay-out). For the client interests it might be best that both approaches, top-down and bottom-up, should interrelate with each other periodically during the design process by means of a middle-up down approach.

5.3.3. Step 3: Putting the possibilities of the AEC industry to use

The activities of the AEC industry vary from design, build, and maintain, to finance, operate and transform, which relate especially to technical and economic business domains. The responsibilities of the AEC industry are currently fragmented and organised accordingly (Vrieze & Moll 2015). It is in the interest of the industry to improve the way they organize themselves in order to deal with current and future demands and make a profit. Therefore it is important to stand still by three capacities the industry has on offer in relation to knowledge, process and products. The results up to here generate more understanding of underlying patterns thereby offering new directions on how (1) to approach the incompleteness of knowledge available, (2) how to approach contradictions between interests and to organize the AEC industry, and (3) how different building products should interrelate.

5.3.3.1. Knowledge

All current issues, especially those relate to the innovation themes, seems to be not addressed with knowledge currently available in the AEC industry only. The introduction of knowledge from outside the industry seems to be necessary, but will increase the difficulties of an already very complex pile of requirements. Systems engineering and introduction of IT tools alone might not solve the problems.

The AEC industry can be decomposed in three groups of *hierarchical* demand and supply chain dependent interests, (1) the fit-out or infill industry; (2) the school management board requested by the municipality to act as the (non-professional) client; and (3) the base building construction sector (e.g. wood, steel or concrete load-bearing constructions). The fit-out industry is a term used in AEC industry to describe the parties responsible for the design, engineering and realisation of interior spaces and mechanical and electrical systems, like ceiling grids, lighting, HVAC distribution and other services, that support the functionalities requested of the building. Also building envelopes, as long as they are no part of the load-bearing structure, is seen as element of the fit-out industry. The base building is a term used for the structural load-bearing elements. In order to coordinate the related processes, the client should have knowledge and overview of these fields. Hennes de Ridder Professor Emeritus Integrated Design chair of construction information and construction processes at the Delft University of Technology argues that a client, in this case usually a school management board, has the responsibility for the co-ordination of the entire design system, which is more than translating the sum needs into a pile of commodities (the highest possible delivery level of the suppliers) and services of specialized suppliers and product designers (Ridder 2011). Therefore it is no rational process of adding up requirements from the brief. Rather it is the clients task to make sure a web can be woven that surprises all and satisfies the different interests of stakeholders at least to a minimum level. This might require knowledge that currently is not available or used in design processes.

It will demand specialized knowledge to put end-users more central in design for example, not only from the psychological domain (e.g. positive psychology, child development psychology, environmental psychology), but also from physiological (e.g. biophysical sciences; sensory sciences), and biological (e.g. neurosciences, medical biology, environmental health) domains knowledge might be required. These domains are better equipped to facilitate the subjective psychological and objective biological requirements of generic end-users needs as well as individual needs. Their knowledge is currently not put to use in the AEC industry.

Differences in the required (scientific) knowledge will lead to a different mix of experts for the base building industry and the fit-out industry. Product development of the fit-out industry that manufactures products, such as modular (class)rooms, will more and more resemble that of integrated industrial products design. The experts required for the base building sector are representatives of the domains that can be associated with the entities of the self-similarity framework. Related to the associative perspective with e.g. sustainable development the table 5.3 illustrates their positions in school building design (see Table 5.4.).

Table 5.4. Entities of self-similarity associated polarity patterns of sustainable development (PESTEL).

Polarity	Mutual/heteronomous development representatives:	Mutual/autonomous development representatives:
Hierarchical/instable development representatives:	Politician	Technician
	-	Economist
Hierarchical/stable development representatives:	Sociologist	-
	Environmental expert	Legal expert

5.3.3.2. Process

In order to improve the process in the AEC industry two aspects need addressing: the organization of the design process itself and team arrangements within the different phases of construction, based on polarity framework insights.

Organization of the design process itself - In order to create an incentive to include the necessary knowledge in the design process the bottom-up approach should receive more autonomy in relationship to the societal approach, which focuses more on heteronomous design interests. This fits to the polarity of the mutual related system scales of different interest clusters that function as a system of levels, ranging from the level of objective societal interests towards the level of subjective individual interests. To organize it in this manner facilitates to improve the quality of school building design.

The primary education related stakeholders and AEC industry stakeholders are highly interwoven and mutual related, which makes their relationship complicated. The school management board has to manage both top-down and bottom-up interests, and fit-out and base building industry interests in a joint middle-up down process. In this approach bottom-up autonomous interests and top-down heteronomous multi-level scaled interests are balanced with the interests of both sides of the AEC industry.

Team arrangements - In order to reduce the social complexity of different interests and the problems within the AEC industry, it is needed to decompose current system of mainly top-down linear organized process into a circular process of interrelated top-down and bottom-up processes and to decompose the current AEC industry at the same time. To translate the educational vision into a material design, different discipline settings can be arranged by the composition of project group (process subsystem level 1); a steering group (process subsystem level 2); a separated team for the base building industry (process subsystem level 3); and, finally team members should have matching roles, in order to allow proper functioning in a team (process subsystem level 4). Base building processes might be managed logically best by the hierarchical (1st project group, 2nd steering group etc.) and mutual (e.g. social needs characteristics) related polarity perspectives belonging to these subsystems. The more parties involved in a collaboration, the more socially complex. The more different those parties are, the more diverse, the more socially complex the process will be (Conklin 2005) (see Figure 5.1.).

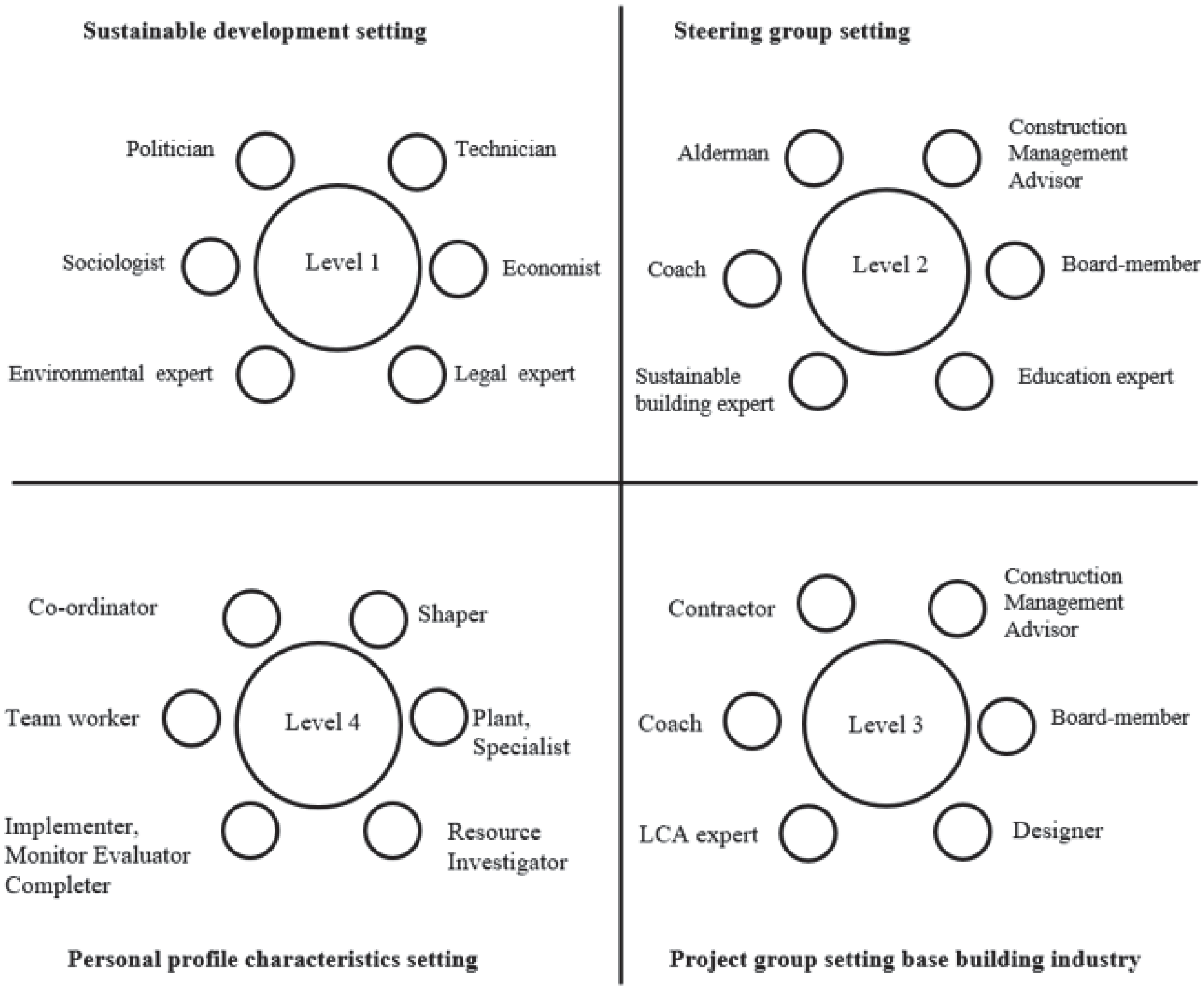

Figure 5.1. Example on how to organize the hierarchical and mutual related aspects for a base building process.

In order to balance not only expertise but team roles as well, a Belbin 'team roles' test can be used to arrange the team setting (Belbin 2011). The systematic of the system polarity framework means that a sustainable buildings expert in life-cycle assessments, for example, should be a type that adheres certainty (see Table 5.5.). This is of course the ideal type while practice can be different. Then still, knowledge of different team roles might help to compose a team.

Table 5.5. Entities of self-similarity polarity patterns team member role system and human needs characteristics.

Polarity	Mutual/heteronomous representatives:	Mutual/autonomous representatives:
Probability entities:	Co-ordinator (contribution)	Shaper (growth)
	-	Specialist, plant (significance)
Possibility entities:	Team worker/co-ordinator (connection)	-
	Implementer, monitor evaluator, and completer finisher (certainty)	Resource investigator (variety)

5.3.3.3. Products

The interaction of economic/technical stakeholders of the AEC industry can be decomposed, but so can the building be disassembled into the products necessary. When aiming to understand the complexity of construction of the building it might be better to approach it via its material components. The development of modular buildings and its subsequent prefabricated components also allows to reduce failures, energy losses, excess transport movements, and waste. A twofold system approach of a product oriented supply chain (fit-out) and a capacity oriented system of base building can improve the balance of interests, while the relation to urban and architectonical context are still respected. Also De Ridder (2011) suggests that a reduction of difficulties can be reached by a clear separation of responsibilities (Ridder 2011). Differences in supply chains might be best characterized by the nature of the products it fabricates. The offsite manufactured products (e.g. modular building components) of the product oriented supply chain, and the capacity oriented sector that constructs the base building or that assembles the structures that define *places* by the placement of the base building (e.g. with a load-bearing construction, masonry work) (Kendall & Teicher 2000). A special feature of the offsite fit-out industry is the growing integrated product design market, which focuses on 'plug & play' components (e.g. bathing rooms, kitchens).

Brand (1994) describes 'sharing layers', that considers buildings as a set of levels, and distinguishes: the site (urban location); structure (load-bearing elements); skin (e.g. exterior surfaces); services (e.g. electrical wiring, heating, ventilation); space plan (e.g. interior lay-out), and stuff (e.g desks) (Brand 1994). Girmscheid & Scheublin (2010) distinguish objective components that form 'places' with modules, integrated elements, prefabricated elements, semi-finished elements and components (Girmscheid & Scheublin ed. 2010). Brand (1994) as well as Girmscheid & Scheublin (2010) have formulated objective approaches that do not have an eye for intra- and intersubjective experiences.

Current brief interrelates the intra- and intersubjective spaces and objective places when designing a school-building. With the new framework the levels of subjective *spaces* and objective *places* seems to be related dynamically, while it allows at the same time for a dynamic relationship with top-down societal needs and bottom-up end-user requirements. End-user interests relate directly to the intra- and intersubjective experiences of the spaces, whilst society relates to objective sustainable development indicators, showing for example that if solutions chosen for the application of materials and elements are circular this might influence the end-user intra- and intersubjective interests. This can cause discussion during the decision-making process when establishing the requirements.

5.3.4. Step 4: Opportunities, probabilities and future changes

So far the results generate more understanding of underlying patterns of the complexity, thereby allowing to include flexibility and adaptability as to anticipate the complexity during the entire design process. The question now is how this framework provides answers to the main three challenges: putting end-users more central, circular processes, and flexibility & adaptability in order to anticipate on future changes.

5.3.4.1. Structural organizational arrangements to facilitate end-users

The new approach based on the polarity pattern framework includes the introduction of a differentiated process of retrieving requirements, by means of a middle-up down approach balancing end-user needs on the one hand, and local community needs on the other hand. This might offer the AEC industry the opportunity to improve their organization now it wants to pay more attention to end-users of school buildings. Open Building is introduced to complete the theoretical framework and the elaborated framework shows it associated similarities with human needs factors. Habraken (2000) coined the term 'Open Building' to bundle a number of different but related ideas about the creation of the built environment. The idea of distinct levels of intervention in the built environment is represented in the physical form by the base building (societal interest) and fit-out systems (end-user interests). Open Building promotes that end-users should been seen as part of the process, and arranges the decision-making processes in such a way that they can make design decisions as well as professionals, but at their own distinct level. Concurrent engineering (e.g. Zaal 2007/2009) also suggests to separate top-down and bottom-up approaches in order to address this properly. Additionally the biophilic patterns support a separation of processes supporting the emergence of a dichotomy of on the one hand bottom up end-users interests related to the infill industry and on the other hand top-down societal interests related to the base building sector. The table illustrates how the identified polarity patterns can be used for the synthesis of an Open Building approach (see Table 5.6.).

Table 5.6. Relationships of the polarity patterns entities in the base-building and fit-out systems vs bottom-up and top-down organization.

Polarity	Mutual/heteronomous base building system entities:	Mutual/autonomous fit-out system entities:
Hierarchical/instable bottom-up system entities:	Bottom-up/base building: Easy to ***adapt*** changes in the space-plan	Bottom-up/fit-out/infill: Hi-tech intelligent ***expandable*** and replaceable services
	-	Bottom-up/fit-out/infill: ***Special infill*** modular buildings/components/ elements (e.g. personal learning environments)
Stable polarity top-down system entities:	Top-down/base building: Site ***connectedness*** (local used materials/social relationships)	-
	Top-down/base building: ***Structure*** (load-bearing construction)	Top-down/fit-out/infill (fit-out): ***Flexible*** facades/exterior

The idea is to organize the design process as some sort of a middle-up down process (Oostra 2013) allowing to address different requirement groups separately while interactions between these separate design processes are sought on a regular basis. Such an approach can meet the subjective, inter-subjective, and objective interests during the design phase towards an architectural synthesis, tolerating the different polarity based interests. The middle-up down process of mutual related bottom-up and top-down interests should not merge the different processes too soon. Molavi & Barral (2016) described the importance of good coordination of fit-out and base building activities, and to take notice of the importance that contractors (and suppliers) are competent to engineer, to build, and to install modules (Molavi & Barral 2016). Time should be needed to balance the different interests to come to an architectural synthesis through dialogues and alignment of interests. Both, top-down and bottom-up approaches of interests can be brought together periodically during the design process. Responsible school-management boards should weigh and tolerate all intra- and intersubjective interests. All stakeholders should have the opportunity to share their interests, including the end-users. To anchor the basic requirements it is recommended to decompose the economic/technical AEC industry, a separation of industries for base building and fit-out. The stakeholders related to the base building can focus on top-down interests (societal, local community), and the fit-out industry deals with the requirements from bottom-up (end-users).

5.3.4.2. Seizing opportunities to stabilize the polarity system with sustainable circular processes

The new framework also might make the transition possible towards a circular approach towards materials and energy resources, as a result of the possibility to balance technological and ecological interests. One of the principles of Open Building is to allow for flexibility and adaptability in the design and the building, since the built environment is in a constant process of transformation and change. Therefore they restructured the way the design is organized. Also the operating and maintenance of buildings is made more resilient in Open Building by allowing replacement of technical systems. What misses in Open Building is the attention for environmental factors. This could be supplemented, as suggested in the theoretical framework of the synthesis by adding the 14 biophilic patterns described by Browning, Ryan, & Clancy (2014). Biophilic Design is an integrated design approach, which considers polarities between space and place, as Habraken (2000) does. In the biophilic patterns the polarities are visible. Seven patterns encompass nature in space (e.g. visual connection with nature), three patterns that form an analogue with nature (e.g. biomorphic forms & patterns) and four patterns concerning the nature of the space (e.g. mystery) (Browning, Ryan, & Clancy 2014). Most of the biophilic factors can be associated with and interpreted as stability factors from the self-similarity patterns (see Table 5.7.).

Table 5.7. Relationships of self-similarity patterns and those from biophilic design (Browning, Ryan & Clansey 2014).

Polarity	Mutual/heteronomous patterns:	Mutual/autonomous patterns;
Hierarchical/instable patterns:	Not identified pattern (the researchers identified here the pattern-similarity with the need for contribution, which defines the term symbiosis e.g. permaculture)	Complexity & order
	-	Biomorphic forms & patterns
Hierarchical/stable patterns:	Material connection with nature	-
	Visual/non-visual connection with nature; Prospect, Refuge, Risk/Peril	Non-rhythmic sensor stimuli; Thermal air flow; Thermal & airflow variability; Presence of water; Dynamic & diffuse light; and connection with natural systems; Mystery

5.3.4.3. Anticipating probable disruptive technological change with flexibility and adaptability

Furthermore the new framework could facilitate in how to deal with the changing needs of stakeholders, by introducing principles to make buildings more flexible and adaptable. Also changes in technology would demand adaptability. For this Open Building was included in the theory used as a point for departure for the synthesis. As already described Open Building introduced principles that restructured the organization of the design process and principles that allow for replacement of technical systems. Hereto a separation might be necessary between base building sector and infill industry as proposed by Open Building. As a result base buildings and fit-outs are distinct systems designed to function separately. Historically this is in line with the trend for more changeable and adaptable buildings that goes back for some decennia now. Cupboards and sleeping alcoves, for example, used to be an integral part of buildings in the past, now they are consumer products. We suggest to treat all infill structures that building users would hope to influence in the same manner. It might generate the opportunity to (partly) decouple the base building from technological probabilities that are rapidly changing.

5.4. Results: a new framework to balance new school building design

From the insights of the analysis a polarity pattern framework is generated. This framework consists of interrelated subsystems based on a consistent constellation of entities organized in self-similarity patterns: (1) the theoretical polarity based hierarchical possibility and probability subsystems and mutual related heteronomous and autonomous subsystems, and (2) the practical subsystems of product and process related entities. These practical subsystems are composed of four elements, each one out of four directions of school building: the base building sector and infill-industry, and the bottom-up and top-down processes with subsequent parties. This whole system is composed of (1) the opportunity pole which mainly focuses on a stable environmental, legal and sociological values of societal and local community interests, which will become visible in the materialization of the base building, the layout of the site and partly in the fit-out of, for example, the facades; (2) the probability pole which mainly focuses on economic, political and technological changes, which usually express themselves first via changing needs from generic end-user groups and individual users. This latter system relates to the infill industry, which uses industrial product design processes to design, engineer and manufacture modular elements (e.g. furniture, partitioning systems and modular classrooms). Both subsystems deliver input to the middle-up down processes for the design of base building and infill as well as top-down and bottom-up approaches. The intra- and intersubjective and objective experiences of spaces and places can thus be distinguished by six layers: (1) stuff, furniture and arrangements; (2) rooms configuration and services; (3) exterior surfaces/fit-out; (4) outdoor spaces; (5) building structure; and, (6) site. The integration of the polarity patterns based approach is illustrated in Figure 5.2.

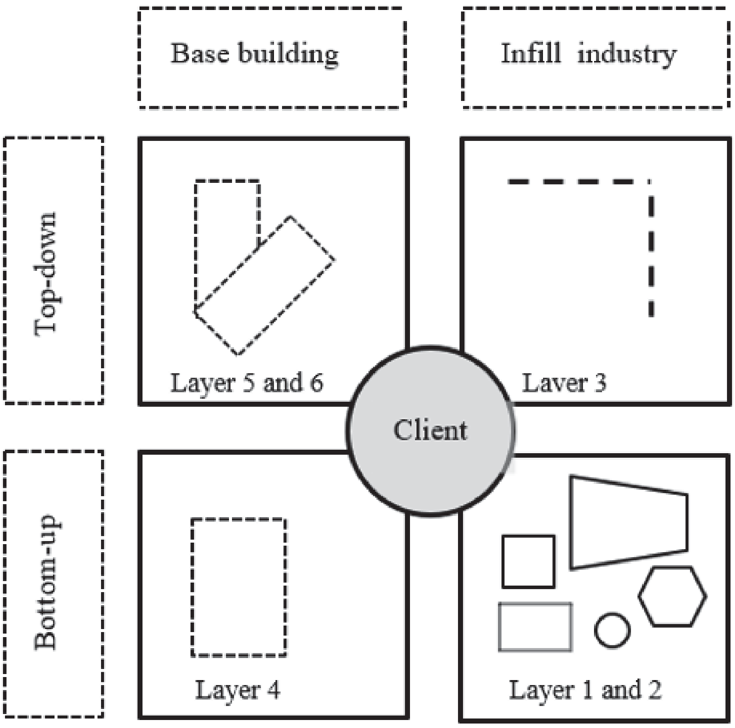

Figure 5.2. Four polarity pattern based approaches within the AEC industry.

Based on this framework a new approach is offered that integrates fit-out components that respect individual and generic end-user interests with a base building that respects local community interests. The guidelines presented below indicate how to include the new framework in the design process (see Table 5.8.). A fictive case is presented in which the practical process is illustrated (see Table box 5.9.).

Table 5.8. Process-Centred guidelines for primary school building design (PCGs).

1	Start with collecting the necessary information from the bottom-up side (end-user) and the top-down (local community) part of the assignment. Also collect information from the fit-out industry components and modular constructions that work according to Open Building principles.
2	Arrange a team that is put together according to the polarity pattern entities. Consider everyone's position and individual profile in relation to needs fulfilment (an education expert, a coach, an AEC advisor, a management board member, a politician and a sustainability expert).
3	Consider the underlying patterns in order to understand the complexity resulting from incomplete knowledge, the contradictory interests and continuous change that demands a design that facilitates this change.
4	Establish a concept programme of requirements that is adjusted to the theoretical polarity patterns framework principles (AEC advisor). In addition, sort the intra- and intersubjective comments in order to make underlying patterns in the process of establishing the requirements phase explicit (coach). This will allow the quality of decision-making to improve.
5	After establishing the programme of requirements, the design phase can start by establishing a project team made up of AEC members (architect, contractor, coach, advisor, board member and LCA expert). The design should be based on polarity patterns and anticipate future changes. It should remain clear that there is no such thing as a static programme for a building. Reality makes the programme dynamic, which can hopefully be incorporated into the layers of changing physical shells that create places (e.g. modules, components, elements and materials) and subsequently spaces (e.g. experiences).
6	Consider the four fragmented polarity patterns that help to facilitate the materialization of the educational vision of the school board.

Table box 5.9. Illustrative example for practical application.

Primary School 'The Imagination', a school-building that is never finished

The school management board requested to support the idea to close a number of small village schools in an area with a declining population in the Northern parts of the Netherlands, and to build a new integrated child centre as accepted by the local municipality council. A new school-building will be built in one of the villages, for which three location are available. The AEC advisor advises to use the new polarity pattern framework (level 1). The municipal council mandates the school management board to manage the whole process and together they establish a steering group (level 2). The management advisor starts after this by establishing the program of requirements thereby integrating, the different perspectives; (1) the local community perspective; (2) the end-user perspective; (3) a base building perspective; and (4) an infill industry perspective. The hired advisor starts as well with collecting information about the available modular systems. Subsequently after collecting the information on a number of hi-tech modules, the advisor starts with collecting requirements from the local community as well as with collecting the end-user requirements. Because the polarity pattern framework is an objective system, the advisor can balance both the intra-and intersubjective and intra- and inter-objective requirements. After this information is collected, the advisor starts with talking to base building sector stakeholders. A catalogue illustrates a variety of measurements and solutions (minds the need for variety). Some of them are hi-tech modular units specifically developed for 21th century skills, and supplied with virtual reality tools (minds the need for growth), others are based on very natural 'Savanna' principles. The catalogue sections are divided in two main sections: 'Security' (targets pupils 3-9 years), and 'Challenge' (targets pupils 9-12 years) designs adjusted to the child-development scales of pupils. All modular components are scientifically proven by a team of social scientists (e.g. environmental psychologists, child-development psychologists), natural scientists (e.g. neuroscientists, endocrinologists), and technological scientists (e.g. fire engineering) (minds the need for certainty). The modular components have a biophilic design. The selected modular components are easily replaceable and prepared to accommodate future changes. A company can deliver the modular *components within one month, and take them back in one month when needed. For the base building stakeholders the advisor hires a coach to guide their personnel during decision-making. The modular building company offers a first sketch and offer. This sketch is used as input for the local community in order to make adjustments to help to fulfil their interests. They decide, for example, on the location, identity of the building, and the use of local materials for the outdoor façade-finishing (minds the need for significance). Local site opportunities and infra-structure adjustments in the surrounded area are explored by hearing people from the local communities. A coach contributes to the process in supporting the local-community (e.g. residents). Meanwhile the end-user process is focused on discovering the end-user interests. In a cyclical process interests of end-users and local community are aligned within different phases (e.g. brief phase, sketch phase). The spaces of the learning environments not only relate to functional specifications of workplace interiors (desks/furniture), classrooms (and separation walls), but also to the outdoor appearance (e.g. playgrounds). The two processes of top-down and bottom-up are interrelated into a middle-up down process. A coach contributes to this process by providing support and by guarding the end-users (pupils, teachers, pedagogues) and local community interests (minds the need for contribution). A last specific step is made by the coach, to make explicit to what extent individual interest are met. The client, advisor and coach contact the base building stakeholders to integrate all developed ingredients and a project group will be established (level 3). When the four fragmented processes are integrated within which the polarities are recognizable, the management board members, the coach, and the advisor can make a next step in the process and select the construction team by their personal profiles in order to collaborate in a smooth working project team (level 4).*

5.5. Practical validation

A group of approximately 12 external stakeholders started with a series of experiments to work on school building design as an 'intriguing question' in the built environment since February 2015. The stakeholders from social sciences and technology sciences came from the following areas: business, governance, research, education and local communities. Within the context of a so called Change Agency 'sustainable buildings' (CAsb), which is a part of the Energy Transition Community (ETC) located at the Energy Transition Centre 'EnTranCe', in Groningen, the group functioned as the Netherlands, a learning community that helped to elaborate new transition pathways for energy and green-house gas reduction (see http://en-tran-ce.org/). The topic for this Change Agency was primary school building design. Monitoring experiments and weekly meet-ups with stakeholders (and students) generated important data to validate the theoretical framework. The stakeholders were asked to establish new pathways for energy transition in the built environment, which cannot be seen apart from sustainable materials, healthy indoor quality, and future real estate value etc. The CAsb adopted the theoretical framework principles step by step. Periodically the participants (often stakeholders in practice) were asked to fill in a questionnaire to increase the awareness of behaviour patterns and to test whether the theoretical framework was understood, adopted, or rejected (see Table 5.10 test 1). Empirical experiments were executed on the one hand to validate the theoretical framework, and on the other hand to verify the practical applicability for practitioners that form a multi-disciplinary team of experts. All group members agreed eventually that something total different has to be done to create a real sustainable school building. However, meanings and opinions vary in the beginning, such as 'it is all about the money', and 'we have to change our behavioural patterns, and therefore at first something terrible should happen that evokes our emotions', the complexity led to the adoption of the theory presented. Because the number of participants increased slightly from the start in 2015, the group had to be separated into two groups, according to the change agency principles for a good collaborating transition group. The group was separated after a transition debate (see Table 5.10 test 2) into a top-down group of societal interests (e.g. a psychologist in behaviour and energy transition, a municipality employee, engineers, architects et cetera), and a group related to end-users (e.g. a PhD in environmental psychology, a biologist, a teacher/initiator of a democratic school, children natural play-ground advisor, permaculture advisor/artists et cetera), which separated on the one hand the top-down and bottom-up interests, but on the other hand it strengthened the bounds between the participants in the different groups. After establishing these two perspectives, and monitoring the relationships between their interests, it increased the willingness to collaborate (they found each other outside the context of EnTranCE as well). A third group could be established later, as a middle-up down group of clients' roles/school management boards (e.g. real estate owner of the Hanze University Groningen, other real estate advisors, a building construction management advisor, school board advisor). In short the organisation slowly evolved into a setting that was rather similar to the context in practice. Elements of the theoretical framework were presented and discussed almost monthly in each group over the period February 2015 until April 2018, and members were experimenting with the extent and meaning of the entities, although for many of them, except for the psychologists, it proved difficult to understand. However, they were intrigued enough to remain involved. The meet-ups sessions led, for example, to the idea to test the autonomous and heteronomous ratios by students (see Table 5.10 test 3). All expert groups were led by the same coach/researcher/moderator, and by their task and position every member was identifying him- or herself with their role. Tests to recognize the human needs, its relationship with sustainable development, and building construction design (the brief and morphology) all has been elaborated in the meet-up workshops to experience and to oversee the value and content for practical application. The relationship with the Belbin test, for example, step by step led to more acceptance, especially when psychologists conformed this aligned relationship triggered them, and so the group, accepted the theory as a new alternative to establish a new school building (a demonstration school building) at the Zernike University Campus of Groningen (see Table 5.10 test 4). At the moment all groups came together it was like coming to a harmonized situation of a remarkable willingness to collaborate when playing an energy saving game (made by two of the participants). That might mean that when polarities are stimulated, instead of merging the wishes, needs and interests together by discussion and trade-offs, it seems possible to come to a flow for collaboration in which there is room for dialogues and consensus (see Table 5.10 test 5).

One of the learning points was how difficult it is to understand each other's social and technical study languages, which makes it hard to share knowledge and information. Although it was a selected team, with which some participants stopped and others joined, the sphere of the group influenced newcomers to become interested to make further steps with the use of the presented theory. Overall it can be concluded that the theoretical framework is difficult to understand, especially for technical oriented stakeholders, and therefore should be applied only in a multi-disciplinary setting with attention for the atmosphere between members. On the one hand the complexity of interests in school building construction is difficult for them to understand, and on the other hand it is hard to understand for them how to implement the offered theoretical framework in practice. The methodology allows stakeholders to see whether their behavior is the result of rational or non-rational thoughts and beliefs, and allows them to see whether a fair balance is achieved between their own and other ones needs. From September 2017 until April 2018 a continuous more intensive reflection has been taken place upon the theoretical framework in different group settings, within the top-down, middle-up down and bottom-up groups. For example, topics involved on the agenda were the recognition of the needs patterns similarities, their relationship with sustainable development, the brief chapter relationship, the design rules similarity, the proposal to separate the different interests groups, and how to organize the AEC. However, this interdisciplinary community of practitioners, and co-working students from social studies, environmental studies, and technical studies contributed in this way the validation of the heuristic of the integrated framework since February 2015 gradually, the next different mutual related validation steps were reported (see Table 5.10.).

Table 5.10. Interventions during the validation to test specific aspects of the theoretical framework.

Validated aspects	Method	Date/year	Participants	Report state
1. Awareness of different stakeholder interests (level of scales)	Questionnaire and test	11 Febr. 2015	9	Internal report (De Vrieze, 2015)
Results test 1: Testing stakeholders' judgement of their position into a three axes model by a Macro, Meso, or a Micro level of scale to realize more awareness of stakeholders' position whether they represent one of the educational and societal interests (e.g top-down, middle up-down or bottom-up), or one of the process stakeholder interests scales. At the moment participants doubt about their position, they were asked to answer emotion based questions, such as 'do you feel yourself responsible for the indoor air quality of classrooms in school buildings, or for executing good policy to facilitate it?'. The participants were at that time not yet separated into a bottom-up and top-down group.				
2. Enforcement of top-down and bottom-up interest differences	Debate	11 Jan. 2016	10	Internal film document on DVD (De Vrieze, 2016)
Results test 2: A transition debate was held to validate the antagonistic differences, led by a hired expert. The group was separated in a top-down and bottom-up group (not all of them agreed with this separation). The awareness of the antagonistic interests between bottom-up and top-down interests, became more obvious when questions were posed about responsibility. Questions like 'do you really have an idea what end-users want as a top-down stakeholder?', or, 'does the top-down group really succeed into an energy transition in practice without consulting the end-user interests?'.				
3. Autonomous and heteronomous percentages and relationship with human needs	Questionnaire	6 Sept. 2017	20	Internal report (De Vrieze, 2017)
Results test 3: Autonomous and heteronomous interests were tested based on integration of human needs in the theoretical framework and a motivation method by the Self- Determination Theory (SDT) of Deci & Ryan (e.g. Deci & Ryan 2002; Martela, Ryan & Steger 2017). Participants and students step by step became aware of their thinking patterns and the balance between autonomous and heteronomous interests, and how it influences the process. A fourth SDT factor, that of 'beneficence' (Martela, Ryan & Steger				

CHAPTER 5: AEC industry interest

2017), seems associated with the 'need for contribution', which should increase the heteronomous ratios when the questions has been taken into account this factor in the tests. The deducted test was published in a psychology magazine 2013 (Zevenhuizen 2013). The experiment was conducted to find out the ratio between human needs autonomous and heteronomous needs. Results: 56% heteronomous and 44% autonomous interests (expected theoretically: 61% and 39%).				
4. Recognition of relationship between Belbin types and human needs pattern similarities	Questionnaire and tests	Febr. 2018	14	Internal report (De Vrieze, 2018a)
Results test 4: In order to establish a process and a group arrangement that fits the type of roles, and to the stated knowledge position, a number of stakeholders were asked to do a Belbin test, using the six human needs as a reference frame. All stakeholders could manage this and there were no obstacles that obstruct this method. The established positions did not adjust perfectly to the group, but the significance of this test was clear. Some other disciplines are needed for a project group of bottom-up end-users infill, and top-down societal more base building related AEC industry. The middle-up down group could also not be fulfilled in an optimal way by the type of roles presented. Subsequently the steering group could be established partly based on the insights on what is expected of the new participants.				
5. Motivation to collaborate after being separated by different interests	Transition game	11 April 2018	16	Internal report (De Vrieze, 2018b)
Results test 5: The separation of the groups into a top-down, middle-up down and a bottom-up group led to a fruitful workshop in which 16 participants came together to play a transition game. Four group settings were established by a spread diversity of these bottom-up, middle-up down and top-down participants. It was remarkable how the stakeholders collaborated together to win the game, despite their different interests (the goal was to win the game by collaboration or by individual interests). Two participants, who are the authors of the game, steered the process. This might explain how polarities in groups settings 'charge' and 'de-charge' after a period of separation, which might contribute to collaborate from different interests perspectives, as observed also by the participants themselves. To merge the interests they should be separated first. By identifying behavioural and emotional patterns, and by managing and by interpreting the type of roles of the participants in the different groups, the process stabilized.				

To illustrate how the response in the validation process was towards of the use of the polarity pattern framework in the different phases, here an overview of the most important insights alongside the different steps in the guideline (see Table 5.11.).

Table 5.11. Insights from the validation process related to the steps of the Process-Centred Guidelines.

No.	Illustrative example of using the Process-Centred Guidelines for primary schools (PCGs)
1	Necessary information is collected from bottom-up (end-users) as a basis for the brief, which will consist of a functional plan layout and requirements of rooms. Comments: The stakeholders in the process could already be separated into a top-down, a middle up down and a bottom-up group. Periodically the interests were be exchanged in order to enable adjustment (note of the stakeholders). The role of an experienced coach proved to be crucial. Top-down (local community) interests were not yet collected during the validation process, however, the top-down group discussed during a validation meeting, the value of a façade, such as "it should be easy to let the façade of a school fit with different communities and local identities". Students collected information from the fit-out industry on components and modular constructions available. The members of the top-down team resembled those necessary for new product development.
2	Teams were composed according to the polarity pattern entities into one bottom-up group, one middle-up down group, and one top-down interests group. Everyone's position was analysed including individual profiles in relation to human needs and Belbin-roles. Comments: The analysis of personal characteristics did not generate any problems, but not every position seemed to have a fit with the personal characteristics. Not all positions could be filled in. At the suggestion of some of the experts involved, we let students fill in the missing positions.
3	The underlying patterns were considered in order to understand the complexity and need for knowledge from lacking disciplines. Comments: different examples and explanation (coaching) sessions made it possible to inform the participants and make them aware of their own behavioural patterns. This proves to raise awareness on how they fulfil their needs individually.
4	A concept program of requirements was adjusted by applying the theoretical polarity patterns framework principles. Comments: For example, a student (he finished his thesis for International Facility Management) elaborated additional design quality indicators (DQIs) for the classroom based on the need for certainty, and for pupils' workplace furniture/desks based on the need for variety. Subsequently the intra- and intersubjective wishes and wants were filtered to make the requirements more explicit (as usually done by architects, but in this validation meeting the architect was assisted by a coach who focussed on psychological aspects). Students from all involved schools, such as Human Technology or Facility Management, still have difficulties with understanding the mechanism and how to balance the interests, although they understand the meaning and theory. That means, better accessible guidelines are desired.

5	After establishing the program of requirements, the design phase can start by the establishment of a project team of AEC members (architect, contractor, coach, advisor, board member, and LCA expert). Comments: The separation of stakeholders in different teams led to a physical separation as well. This led to preparations of outdoor arrangements/load bearing construction/services and facades delivered as base building elements (physical shells) separated from the infill elements/components that could be (re)placed or (re)moved easily by modular or even self-made systems from circular materials.
6	During guideline step 5 the four fragmented polarity patterns (autonomous vs. heteronomous and stable vs. unstable aspects) helped designers to facilitate to materialize the educational visions of the school board. Comments: The approach was hard to implement, but the significance of the theoretical framework was clear. The initiators of (in this case) the demo-school could elaborated on the educational process and explained it to the group. The mutual related interdependency between society, local community, school boards, end-uses and individual end-users resulted into a consistent end-result with more impact from heteronomous aspects than from autonomous aspects. This meant that in the end that, for example, the individual end-user had the lowest impact on the whole, but enough to change the own physical workplace, such as supplementing additional warmth or fresh air.

5.6. Discussion and suggestions

Finally some elements for discussion and a few suggestions:

<u>Coach necessary for successful application</u> – The new approach has effects on behavioural patterns that influence the decision-making processes. In the validation process it became apparent that the introduction of a specific schooled coach is required to guide the stakeholders through the process. This is necessary because of the complex context of the design process in which the approach is used. When an already complex process is further burdened with additional requirements people can get overburdened, especially when also three main innovation themes are introduced: a more centred position of the end-users, the circular approaches, a flexible design process and building. Suggestions are made to improve the process by managing the arrangement of stakeholders involved. This is also based on the insights that result from the polarity pattern framework. The integration of the design process will be co-ordinated by the school management board from a neutral position in the democratic decision-making processes. All stakeholders are individually screened to make an inventory of their subjective personal needs and fit with their negotiation positions. It remains to be seen if the coach remains necessary when people become familiar with the new approach.

Practical testing – The authors realize that this chapter is only a start of the development of a new approach. More research and practical testing is needed before its true value can be estimated. The new framework is validated preliminarily in a practical setting of stakeholders from social studies, environmental studies and technical studies during a range of several topic discussion sessions, and the 5 reported test sessions. It is indicated how to integrate the framework in a design process in the Process-Centred Guidelines for primary school-buildings (PCGs). These should of course be further tested in practice. A primary school realized based on a design made according to this new developed framework is currently lacking, and is therefore a next step in our research.

Additional research - When analysing the interests within the different themes of people, planet and possibilities, it became clear that the different factors in, either human needs and interests, educational requirements, environmental aspects and AEC industry interests are actually fractals. When looking at a specific element, links to other elements became apparent. This makes it sometimes look as if all elements are mirrored within the other elements. A clear separation of the three different themes in the analysis is therefore difficult. The positive site of it is that it offered a web of starting points for the system synthesis. These fractal-like elements are probably typical in an integral research approach, but are new to us as researchers and probably also for most people in construction. Therefore time and effort in additional theoretical theory development and practical application is necessary. Only then it will become possible to get a better idea of the implications, consequences and possibilities of this approach.

Theory development – Similar polarity-based patterns are found in human needs & interests, sustainable development factors, program of requirements sections, building design morphology, building components, knowledge domains and types of stakeholder roles that all support the idea of the presence of universal underlying polarity patterns that help to ameliorate the quality of the physical and social translation process of school building design. With its foundation in biophlic design, comparison studies should be made with other design theories to learn if there are other interesting connections, for example, the Gestalt principles (e.g. connection, closure, similarity et cetera) and the Panarchy Theory (e.g. connection, potentials et cetera) (Gunderson & Holling 2002). Contradictions can be found as well, for example, when comparing with dialogue mapping (Conklin 2005). At first sight the theories match very well. When looked at more thoroughly, it becomes clear that dialogue mapping lacks the possibility to connected to the underlying polarity patterns and self-similarity of different system scale entities as presented in this chapter. It might not be expected that all stakeholders will follow the suggested objective pathway of universal polarity patterns, and they might even engage a totally unexpected manner. This fact can even be explained by the theoretical framework presented, namely, as a result of the human need for variety, manifesting itself in a personal urge to be less predictable and more vulnerable.

Implications for education - The introduction of the opportunity pole that contains the People, Planet, and Possibility dimensions, offers stability to the subsystems of the framework that permits to address the different innovation themes. The probability pole, which incorporates technological, economic, and political factors, will have destabilising effects on the framework as a result of the contradictories it introduces. The sustainable development factors and social system theories introduced in this chapter are generally accepted in theory. During the validation process it became clear that it is not easy to understand the polarity-based framework, let alone working with it. Participants with a social sciences background had less difficulty to understand the topic, probably because they already had some theoretical basis to which the polarity-based framework could be linked. Question is what implications to draw from this insight. It could be an indication that it is needed to integrate insights from complexity and CAS theory in the curricula of construction related studies.

Facilitating technological change - The polarity pattern framework introduced in this chapter suggests that a better architectural synthesis can be achieved when addressing universal polarity based patterns within social and material systems. These interactions influence the process in which requirements are determined. Current approaches lack the integration of these patterns and a way to deal with subjective and non-rational interventions that affects decision-making. School building should not start with simplification and compromise of interests, but should start with an end-user program of requirements on the one hand, and a local community program of requirements on the other hand. With the introduction of the framework introduced in this chapter, a polarity-based system is introduced for the current construction industry to enable the integration of knowledge from new disciplines into building product design. This provides the potential to make school buildings both sustainable and intelligent. For this the proposed separation between base building sector and infill industry as proposed by Open Building is necessary. We suggested to treat all infill structures that building users would hope to influence in the same manner. Additional value could be included in these infill products, making them smart and circular. This would then lead to a complete new industry of consumer products that could tap into the possibilities new technologies have to offer towards clients and end-users, for example, 3D-printing, IoT and building robotics. In Japan this is already happening as a result of a thorough implementation of Open Building principles. This might certainly have major consequences, which are difficult to oversee.

No panacea - To solve the stated problem for AEC industry is not possible, but more understanding of it and the introduction of room for future adaptation might be achieved by a clear sight on the underlying polarity patterns. Also external influences on the polarity system as a whole can still destabilize the generated system of People, Planet and Possibilities when the capacity for resilience is overcharged. The theoretical framework introduced in this chapter encloses an interrelated multi-level system consisting of two internal system polarities: autonomous vs. heteronomous and stability vs instability factors. These polarities relate to external directed system polarities of upper or lower hierarchical levels. A balance can only be achieved while incorporating internal and external factors.

The consequences of the possibilities (remember/ legal/ variety) as an entity of the stable opportunity and autonomous system, and potentials (revolt/ political/ contribution) as an entity of the unstable probability and heteronomous system implies that system levels keep changing while searching for internal and/or external balance. That also implies that the translation of educational visions into a material design keep on changing with an increasing speed. For example, political changes might result in an intervention in the probability system, such as for example the introduction of multifunctional accommodations (MFAs). In this case legal policy might need time to incorporate this change. The AEC industry should get prepared for rapid changes, considering the unbalance of the current system and rapid developments in technology. Although it is a theoretical approach, the probabilities system seems to search for balance with upper systems, while the possibilities system appears to search for balance with conservative, or lower system levels. The system model as a whole illustrates the relationship of sustainable development on multi-level scales. Systems change over time and will be influenced by other system scales. Considering this reasoning, current technological developments might cause disruptive change in school building design that might influence current design typology. From this point of view, current problems and dynamic changes of school building design simply shows a structure with a weak coherence.

5.7. Summary and conclusion

This chapter started with the introduction of earlier research analysing the persistent problems in primary school building design. The problem analysis resulted in the conclusion that a new framework for primary school building design should be developed in order to deal with its complexity. The research question in this chapter therefore is: can a framework for the school building design process be realized that helps to deal with the complexity in school building design, based on the understanding of the interaction patterns between interests, the different clusters and levels in which these interests organize themselves and the relationships of these interests, clusters and levels?

The interests to include in the framework were clustered in three groups: (1) psychological, social & educational, (2) environmental and (3) the interests of the parties from the AEC industry. Theory of sustainable development process on the evolved triple bottom line (people, planet, possibilities) and the PESTEL-factors was used, together with theory looking at processes of flexibility and adaptivity to construct the framework. For a link to construction, the theoretical synthesis framework was completed with Open Building and Biophilic Design.

The synthesis was based on the analysis of the three aforementioned interest groups. The four steps of the synthesis were: (1) constructing the basis of the framework based on environmental requirements, (2) adding the people perspective by including psychological, sociological and educational interests, including the interests of its institutional sector (e.g. Dutch council for primary education POraad), (3) adding the interests of the AEC industry and its institutions, and (4) establishing the framework by looking at opportunities, probabilities and future changes.

Finally the outline for a new approach was introduced and tested in a series of validation studies. Also Process-Centred Guidelines for primary school-buildings (PCGs) were presented which were validated in a series of expert meetings.

As a result all people, planet and possibility factors were integrated into one coherent framework, including all social and environmental interests with the interests of the physical world of school building design and the AEC industry. As this industry faces the challenge to respond to the myriad of interrelated interests and to incorporate the ambition of the industry not only to improve the quality of new primary school buildings, but also to include three innovation themes: end-user centeredness, sustainable school design and adaptability to future changes, this framework seems to be created at the right moment.

For research the framework offers an interesting basis as well, ranging from further theory development, additional research and practical testing. Further research can help to generate additional insights that help to understand the complexity as a result of behavioural patterns, and provides the possibility to identify underlying polarity patterns of contradictories. Furthermore it can be of help by recognizing incompleteness of the knowledge available in the process, and help to create a better understanding of the mechanisms that accompany change. The theoretical framework synthesized is made to provide insight that will foster the emergence of new strategies to deal with the non-rational behaviour in the AEC industry.

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Chapter 6
CONCLUSION

Results & recommendations

6.1. Introduction

Several institutions report a variety of persistent problems in Dutch primary school building design and the design processes. These problems affect school building and end-users' performance and ultimately, society as a whole, as well as the entire AEC industry construction sector. Although financial, political and technical measurements have led to some improvements, these problems have not yet been resolved. The central hypothesis of this thesis is that this is due to unawareness and poorly understood influences of the underlying patterns. An expansion of the analysis is required with other factors that represent the social, environmental and process-related interests. Recognizing the value of these social, environmental and process-related factors allows a better understanding of the design and processes and a balance to be achieved with the conventional financial, political and technical interests. Therefore, social, environmental and building construction process studies were used to answer the main research question: '*how to improve Dutch primary school building design from an integrated perspective of interests?*'

To disentangle the myriad of specific interests related to school buildings and school building processes, a system analysis was performed. Different scales were distinguished – from macro to micro – and different dimensions were considered: human social needs factors, sustainable development factors and school building design factors. Lastly, it is suggested that the school building problem may be solved by restoring a balance between the needs of all relevant actors by considering their interests.

Chapters 2 and 3 describe the first part of the study. These chapters explain in more detail how human needs and behavioural patterns influence school building design and how these were identified as the main causes of the school building problems. For example, the unawareness of underlying social patterns of intra- and intersubjective and related intra- and inter-objective interests. Different relationships were identified within multiple levels of subjective and objective interests.

Chapter 4 elaborates on the sustainable development dimension. A relationship between intra- and inter-objective interest characteristics and collective group interests was identified that connects the sustainable development factors to the human needs.

Chapter 5 describes how all interest characteristics were amalgamated and integrated into a single holistic view of how human needs, sustainable development factors, design morphology and process factors and rapid global changes balance the intra- and intersubjective and intra- and inter-objective interests.

The theoretical framework developed as part of the study is summarized and discussed in section 6.2 of this concluding chapter. The practical instruments and guidelines are presented and discussed in section 6.3. A brief reflection on the validation methods used is presented in section 6.4 and some recommendations are given in section 6.5. The final part of this chapter, section 6.6, comprises the general discussion and conclusion.

6.2. First outcome: development of and reflections on the theoretical framework

Regarding the theoretical development, the findings of the study can be summarized as follows for each chapter.

Chapter 2 describes the generation of an integrated needs-centred framework and instruments as a basic model for further specific diagnostic analyses. This generates more awareness of cyclical processes through a conscious integration of human needs. By using this framework, pathways could be developed that might achieve more positive responses, generating more synergetic approaches with new intelligent technology and a greater awareness of the importance of human factors. The framework also has the potential to contribute more broadly to defining the fundamental parameters of the various learning environment scales, which in turn allow us to better anticipate future developments in personal learning environments.

Chapter 3 elaborates on human needs-related principles and a step-by-step plan based on the basic model and instruments – the main outcome of chapter 2 – with a view to achieving a better balance within the continuum of societal and end-users' interests. We therefore generated detailed design quality indicators to develop the physical learning environmental shells and to meet general and individual end-users' needs. Hence, defining sustainable, healthy and innovative school buildings should start explicitly with generating more awareness of end-users' subjective psychological and physiological basic needs. In this way, technological adjustments may contribute to serving integrated end-users' objective biophysical interests.

Chapter 4 describes the development of a theoretical framework of social and ecological factors that are able to deal with sustainable development principles and issues in the context of primary school building design. This framework incorporates qualitative and quantitative factors and uses social system-linked and ecosystem-linked similarity patterns to define a stable set of entities to frame the decision-making processes. The method involves several detailed characteristics, considers multiple levels and generates a new guide for practical application.

The development of a new framework for primary school building design is described in chapter 5. This framework was developed to deal with the complexity of school building design and is based on an understanding of the interaction patterns between interests, the different clusters and levels in which these interests organize themselves and the interrelationships of these interests, clusters and levels. The interests included in the framework were clustered into three groups: (1) psychological, social and educational interests, (2) environmental interests and (3) the interests of the parties from the AEC industry.

The synthesis was based on the analysis of the three interest groups mentioned above. The four steps of the synthesis were: (1) constructing the basis of the framework based on environmental requirements, (2) adding the 'people' perspective by including psychological, sociological and educational interests, including the interests of its institutional sector, (3) adding the interests of the AEC industry and its institutions and (4) 'future-proofing' the framework by looking at opportunities, probabilities and future changes.

The system analysis revealed three drivers for change as the main outcome of the three dimension studies. This changes the preliminary model (see Chapter 1, *Introduction*) into a three dimension model that incorporates intra- and inter-objective and intra- and intersubjective factors to balance the system:

1. The recognition of six entities that interrelate the multiple levels of six human needs factors, six sustainable development factors and six school building design process factors (see Figure 6.1.);
2. The recognition of two polar opposites of autonomous/heteronomous and mutual/hierarchical directions that balance the integrated system (see Table 6.1.);
3. The recognition of internal system and subsystem balances and external system influences (see Figure 6.2).

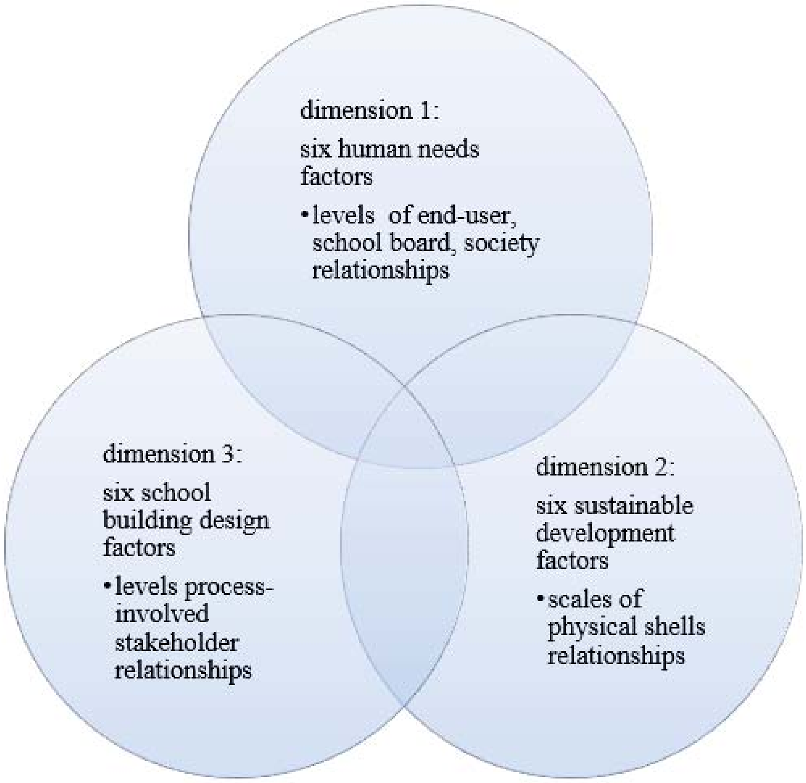
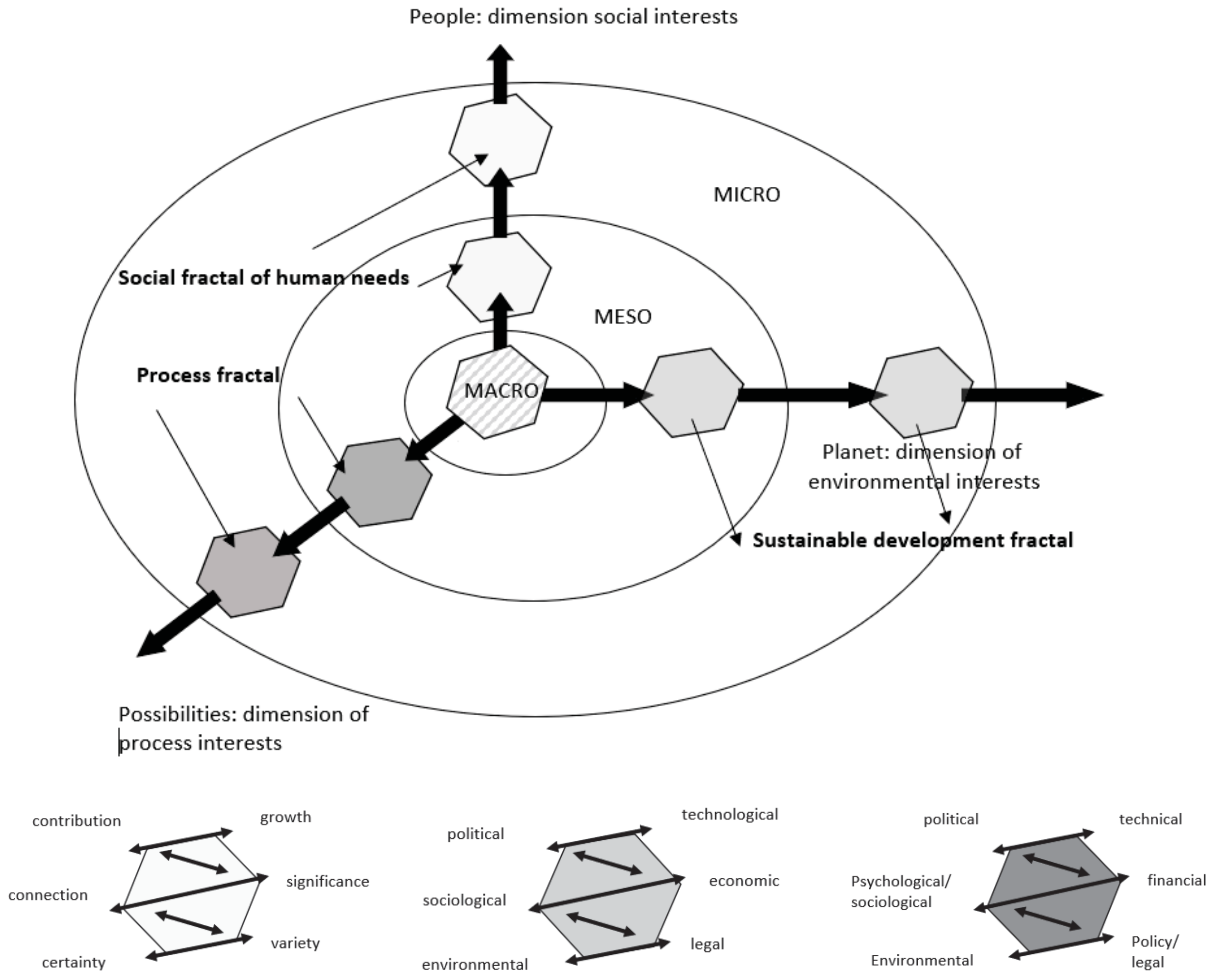


Figure 6.1. Three interrelated and balanced stable multi-level drivers for change.

Because of the mutual and hierarchical relationships identified between the self-similarity patterns and multiple levels of social systems, ecosystems and related design and process systems (all striving for a stable balance), the research focused particularly on achieving a stable system balance. This was realized by using the fractals developed: the social fractal of human needs, the sustainable development fractal and the process fractal (see Figure 6.2.).



People: social fractal of human needs **Planet: Sustainable development fractal** **Possibilities: Process fractal**

Figure 6.2. The three dimensions of self-similarity patterns for stability.

One country in which the 3P concept took deep root was the Netherlands. Elkington (2018) argued that his original idea was to encourage businesses to examine the company's social, environment, and economic impact, however, a recall is needed (Elkington 2018). To complete the new generic model from a synthesized approach, three stable (so called opportunities), and three unstable (so called probabilities) dimensions, together the six entities of self-similarity patterns, can be described by six "P" references. Two added "P" descriptions are desired to complete the new 6P model based on the six entities. Therefore the terms 'Particularities' and 'Proliferations' are chosen by their associated intensions. For example, the term 'Particularities' relates to the need for personal significance and economic development. The term 'Proliferations' relates to the need for personal growth and technological development. The stable opportunity dimensions are People-Planet-Possibilities, and the unstable probabilities dimensions are Particularities-Potentials-Proliferations. The final established generic six 'P'-model balances the different interests multi-level scaled by the six entities (see Table 6.1 and Figure 6.3). This synthesis generates now an integrative picture to balance all recognized self-similarity patterns multi-level scaled. This approach led to a simplification to understand the polar and dynamic system complexity from all integrated perspectives.

CHAPTER 6: Conclusion

With the new presented 6P model in this chapter is referred to chapter 5, within which these six dimensions are developed profoundly (see e.g. chapter 5 Table 5.4). This theoretical system analysis-based approach led to a simplification of Dutch primary school building design and to an understanding of the current design complexity. The universal or unified factors or dimensions can now be described as generic entities of self-similarity and polarity patterns, within which the continuum form intra- and intersubjective (individual and generic needs) to intra- and inter-objective scales (disciplines and sustainable development factors) can be related interconnected consistently (Table 6.1). The synthesis delivers a 6P model that balances the locked-in different multi-level interest characteristics through the entities derived from the results described in chapters 2, 3, 4 and 5 (see Figure 6.3.).

Table 6.1. Generic entities of self-similarity and polarity patterns.

Polarity	Heteronomous polar entities	Autonomous polar entities	System stability
Unstable polar entities of *probabilities*	Entity 5 (Potentials) Intra- and intersubjective: need for contribution Intra- and inter-objective: political factors	Entity 6 (Proliferations) Intra- and intersubjective: need for growth Intra- and inter-objective: technological factors	Unstable system
	-	Entity 4 (Particularities) Intra- and intersubjective: need for significance Inter-objective: economic factors	
Stable polar entities of *opportunities*	**Entity 3 (People) Intra- and intersubjective: need for connection Intra- and inter-objective: sociological factors**	-	**Stable system**
	Entity 1 (Planet) Intra- and intersubjective: need for certainty Intra- and inter-objective: environmental factors	**Entity 2 (Possibilities) Intra- and intersubjective: need for variety Intra- and inter-objective: legality factors**	

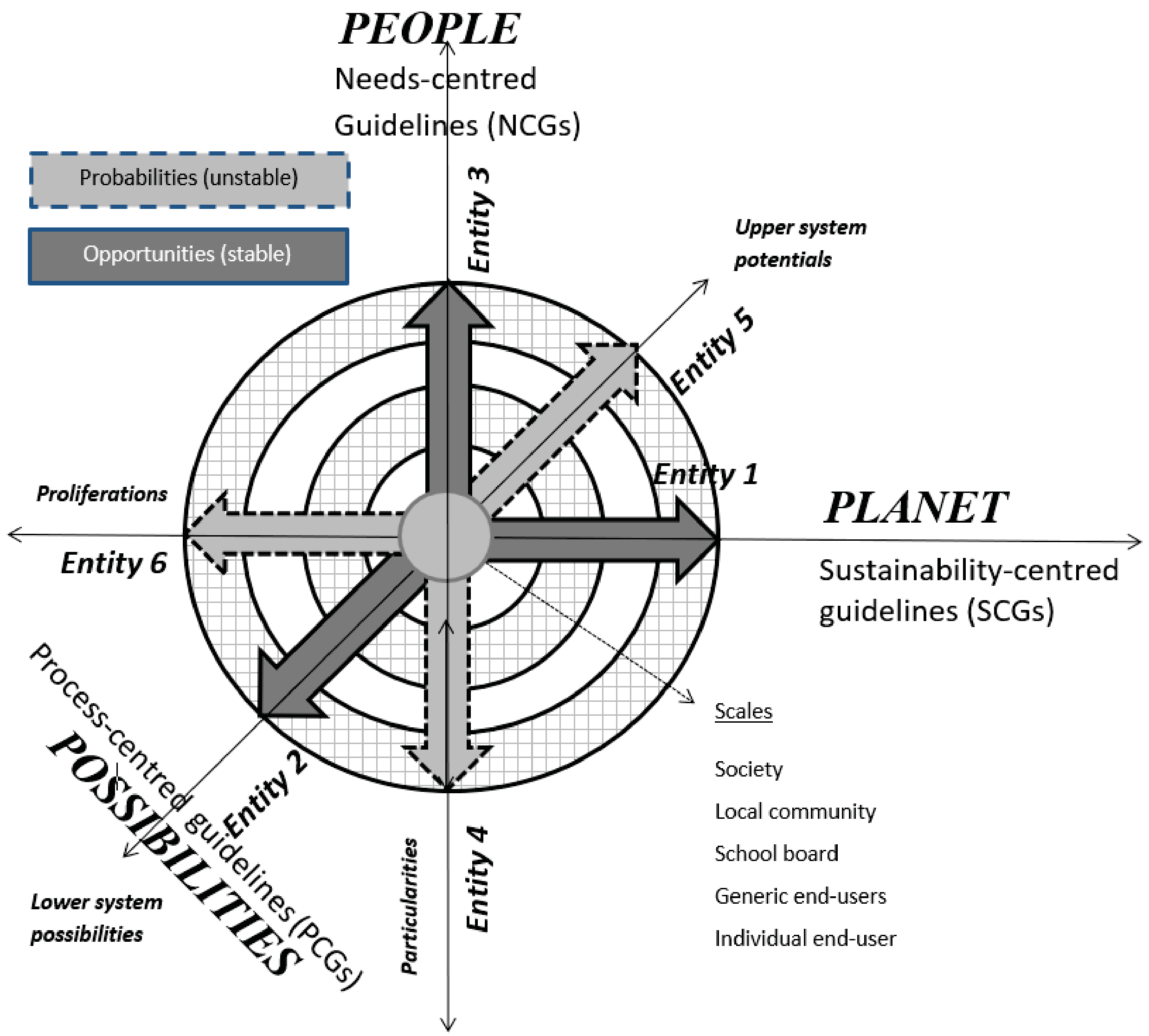


Figure 6.3. The multi-level scaled 6P balanced model.

The value of the pattern similarities became increasingly significant as the study progressed. From a growing awareness of these consistency patterns between the six human needs factors, six sustainable development factors and the six building construction design and process-related factors, the self-similarity patterns and associated mutual and hierarchical polarities developed influence the system stability on multiple levels. Based on the introduction of the new framework, it became apparent that a possible solution is not to be found in current approaches that prioritize financial, political and technical factors. Instead, this system should be stabilized by increasing the contributions of environmental factors, legal possibilities/ambitions and sociological impacts, and by reducing the contributions of the financial, political and technical factors. Both sets of factors are necessary and all factors should be weighted by their impacts. Using the 6P system entities, the theoretical framework led to a focus on attention points for school building design.
Table 6.2. shows an example of how these attention points can contribute to find new searching directions and integration of stakeholder different interests. Here the largest influencing factor of the 'Planet' axis from the 6P model is used, so called entity 1. Entity 1 emphasizes attention of four types of scales of interests addressed

by, in this case only the intra- and intersubjective system influences of human need for certainty to the intra- and inter-objective system of environmental disciplines and sustainable development factors. These types of interests are related to physical design and process scales (by interior end-user and exterior societal perspectives) and to the multi-level subsystem of different interests perspectives: the social scales of bottom-up end-users (pupils, teachers); middle-up down school management boards, local governmental officials; and top-down society, national government; and, the process group of AEC industry stakeholders during the design process. This example interrelates the problems by integration of the different subjective and objective interest systems and physical multi-level design scales. This approach makes clear how these systems interact, on the one hand, like fractals and to a simplification of Dutch primary school building, on the other hand, it shows the complexity for practical application. These interest scales correspond to the chapters, although these chapters recognize the subjective and objective interest scales only implicitly. All four scales of interests are addressed in Table 6.2 column 1, and references to the relevant chapters are given. Individual subjective interests include thoughts, beliefs, emotions, behaviour and sensory experiences of school building design, whilst collective subjective interests include local identity and cultural school building design interests. Individual objective interests include social and natural and environmental sciences, and building construction methods, whilst collective objective interests include ~~ecosystem relationships~~ sustainable development factors. Column 2 shows how these different interest scales relate to the top-down, middle-up down and bottom-up interests of physical school building design elements and to the AEC process scales. Column 3 shows the different stakeholder interests and attention points for the material design interest relationships considered from an entity 1 perspective.

Table 6.2. Example of integrated points of attention extracted from the 'Planet' entity.

Entity 1: Planet		
Intra- and intersubjective and intra- and inter-objective scales	**Physical design and process scales**	**Integration of stakeholder interests** (see chapter 5 Table 5.4). Used terms: Certainty; Functional; Structure; Environmental
Individual subjective interests (chapters 2, 3)	Interior design shells: furniture, classrooms and indoor layout	Bottom-up: the interior setting of the school building allows individual end-users to feel safe at school; Middle-up down: the layout of the school building allows school management board officials to feel in control about the execution of their educational program, operations and maintenance; Top-down: Local community stakeholders want to be able to rely on acceptable indoor air quality levels.
	Process: decision-making	AEC industry: stakeholders involved in school building design should be aware of their own need for certainty during decision-making and consequences for environmental issues. They should therefore be aware of how their personal need for certainty intervenes with integration of disciplines outside financial and technical domains that are required to support individual interests (e.g. inclusive education).

Collective intersubjective interests (chapters 2, 3)	Exterior design shells: building design, playground and surroundings	Bottom-up: end-users want the exterior, the surrounding area and the road to school to be safe and secure; Middle-up down: school boards want an exterior that expresses their educational vision and use of the school building; Top-down: local communities want an exterior design that expresses their local community's identity and culture.
	Process: incorporation of environmental sciences (ecological footprints, Life Cycle Assessments (LCA) et cetera.	AEC industry: the industry wants to decrease the complexity of the design process and focuses on simplicity of structures to feel certain about the process.
Individual objective interests (chapter 3)	Design: learning environmental factors	Bottom-up: individual end-users want to have learning environments that fit in with their biological, physiological and psychological interests; Middle-up down: school boards want flexible learning environments that can be arranged according to educational needs and controlled & maintained well; Top-down: local communities do not want hidden environmental impacts and costs of poor future-proof and less adaptive school building facilities.
	Process: building construction methods	AEC industry: stakeholders involved focus on the value of their own specialized discipline related knowledge and recognizes the need for adding e.g. social and environmental studies.
Collective inter-objective interests (chapter 4)	Design: sustainable development relationship and ecosystems	Bottom-up: end-users (e.g. pupils) interests are based on functional learning environments; Middle-up down: school management boards want to strive for future robust school building designs; Top-down: society aims to become sustainable and therefore looks for ways how to realize ecological school buildings that fit in with their environments and aims at more simplicity of building design structures (e.g. offsite).
	Process: urban development, built environment and building construction relationships	AEC industry: stakeholders involved want more focus on sustainable school building design that considers to a greater extent the balance of sustainable development.

Table 6.3. shows an example of how the persistent problems can now be better understood and what recommendations the theoretical framework, instruments and guidelines that were developed can offer. The developed model delivers recommendations and contribute to provide a better understanding of the problem causes. For example, 13 most general problems reported by the Dutch RVO (Netherlands Enterprise Agency) (RVO 2014) are used as a source to generate recommendations by using the 6P model (see Table 6.3). This table illustrates how different interests, level of scales and imbalances cause persistent problems, and how recognition of the entities (generated by the human needs fractal, the sustainable development fractal and the process fractal) contribute to more awareness of subjective and objective domain influences and

autonomous/heteronomous and stable/unstable polarities. A brief analysis of the most frequently occurring problems shows how all the recommendations implicitly lead to a synergistic solution. This can be achieved by means of an Open Building method that fits in with integrated product design components that are produced offsite, thereby separating the physical school building design into a top-down and a bottom-up approach.

Table 6.3. Problem scale analysis and recommendations.

Problems as formulated by RVO (2014)	Recommendations following from the new theoretical framework
1. Poor collaboration between municipalities and school management boards	*Problem scale analysis*: top-down and middle-up down stakeholders differ by their levels of interests, for example, financial, political and social/educational levels (e.g. investment versus operational and maintenance costs). Furthermore, subjective interests can lead to non-rational behavioural patterns of stakeholders in decision-making. *Recommendations:* dividing different parts of the physical school building design among different stakeholders, e.g. assigning facade design as a top-down responsibility (e.g. municipality) and make the design of classrooms a middle-up down responsibility. The sustainable development fractal may be helpful in establishing a better balance between the levels of built environment scales, such as the prioritization of the top-down heteronomous interests (exterior) slightly above the middle-up down autonomous interests (interior) stakeholder interests. The final ‘brief’ should be a synthesis of top-down, middle-up down and bottom-up requirements, which divides the interests and physical shells in a well-balanced manner. By separating the interests according to the physical building shells, the subjective influences of all stakeholders will be balanced too. The human needs fractal can contribute to establishing the balance quantitatively.
2. School boards’ lack of experience of school building design processes (how to be a professional client)	*Problem scale analysis:* technical domain-dominated stakeholders and disciplines expect from clients that they have technical knowledge, but they have in particular knowledge of social sciences, e.g. education. *Recommendations:* dividing the design process of stakeholders into teams based on both bottom-up and top-down perspectives. The human needs fractal may contribute to filling in the lacking experience that defines the ‘brief’ requirements. Encouraging the AEC industry to focus on infill industry on the one hand, such as modular design (e.g. plug ‘n play tradable commodities), and on prefab base-building design made by the off-site industry on the other. Both recommendations contribute to achieving a stable balance.
3. Internal organization and interests of municipalities that are too complex	*Problem scale analysis:* municipal department responsibilities affect school building because of different levels of interest of politics, social/education policy, enforcement policy and finances. *Recommendations:* reducing the complexity by decentralizing interior physical shells to become the middle-up down stakeholder’s responsibility (e.g. financing plug ‘n play classrooms produced by the off-site industry).
4. Distrust between market parties that affects good collaboration between teams	*Problem scale analysis:* market parties are involved with a diversity of intra- and interdisciplinary stakeholder and business interests and conditioned views of conventional school building. *Recommendations:* if the off-site market (e.g. infill industry) becomes more influential in the conventional construction sector, it will displace traditional processes by assembling integrated product design components. The process fractal may contribute to establishing a better balance between the stakeholders involved.

5. A fragmented responsibility within the supply chain market	*Problem scale analysis:* the demand side represents a wide range of intra- and interdisciplinary stakeholder and business interests which results in a wide range of solutions the supply chain should be able to offer and the associated complex processes. *Recommendations:* the AEC industry could reorganize its processes according to the base building - fit–out division Open Building proposes and focus on the new business opportunities the development of a fit-out industry with plug & play customized products has to offer.
6. Lack of innovations in the AEC industry	*Problem scale analysis:* the AEC industry still deals with methods that are based on traditional school building and technology-dominated disciplines. *Recommendations:* good illustrative examples from the off-site industry (integrated product design) may help, as a lever for change, in convincing conventional AEC industry stakeholders to change their design methods. The 'human needs fractal' and the 'process fractal' may contribute to establishing a better balance between the AEC stakeholders involved.
7. Underspending municipality budgets	*Problem scale analysis*: top-down political, financial and sociological demographic uncertainties influence the reserved budgets, and affect the middle-up down's needed investments to improve the school building quality. *Recommendations:* considering the rapid global changes, new school building design should take into account future changes. Disinvestment risks can be reduced by harmonizing the functional, economic and technical lifetimes of buildings. School buildings should be capable of adapting to future changes, which may also create new opportunities to reduce the investment costs of new school buildings if the building were to be designed for shorter periods than is currently the case. New school building design should be based on letting school management boards operate and spend their budgets more autonomously.
8. Introducing new legislation rules and uncompensated budgets	*Problem scale analysis:* top-down introductions of new policies by different ministries, interrelate with the budgets and affect the scale of local community interests. For example, problems may occur when a new educational policy (e.g. inclusive education) is introduced without considering the budgets and technical school building consequences in time. *Recommendations:* the different ministries involved should harmonize the consequences of new policies, but it is not expected to happen. Therefore, school building design could take into account future changes during the design decision-making stages.
9. Operational costs that conflict with investment and pay-back periods	*Problem scale analysis:* top-down municipality (investment responsibility) and middle-up down school management boards (operational costs responsibility) differ, also known as split incentive. *Recommendations:* if investment costs and budgets for operation and maintenance are split between the municipality and school boards, the boards can function more autonomously and a better balance may be achieved by thinking in terms of 'total cost of ownership'.
10. Lack of maintenance and legislation enforcement	*Problem scale analysis:* different top-down political interests and policy interests affect the middle-up down and bottom-up interests as illustrated by the persistent problem of poor indoor air quality in 70-80% of Dutch primary school buildings. *Recommendations:* school boards are responsible for indoor environment issues, a solution could be to make new designs IT-controlled, steering the automated systems to generate the biological climate as required.

11. Energy reduction measurements conflict with increasing indoor air quality	*Problem scale analysis:* top-down interests of the environmental issue scale, such as energy reductions affect the smaller scales of the indoor environment of middle-up down and bottom-up scales. *Recommendations:* different climate zones in new school building design could be incorporated to fulfil the psychological (cognitive), physiological (sensory) and biophysical (bodily) needs, which also synchronizes with top-down interest of energy reduction when approached naturally (e.g. using biophilic design and/or passive solar energy).
12. Roles of stakeholders operating on the demand-side are unclear	*Problem scale analysis:* bottom-up stakeholders, such as parents, teachers and school directors, generally do not complain about the energy use, indoor climate quality and the general quality of the school buildings; a phenomenon that relates to a lack of autonomous influence. *Recommendations:* this demand side may improve the school design quality with increased awareness of the fractal-based mechanism and school building complexity. Therefore, they could focus more on simply measuring the health of the indoor air quality (e.g. indicatively by using cheap digital applications).
13. Educational institutions fail in supporting school boards in stating their programme of requirements	*Problem scale analysis:* the complexity to understand the problems cannot be done without considering the different interests and disciplines, the level of scales and how these can be balanced in a field of intra- and intersubjective and objective system mechanisms. *Recommendations:* the middle-up down position should merge the different interests (top-down, bottom-up and their own interests) after an understanding has been gained of the human needs, sustainable development and process fractals, polarity and time and emotional impact-related factors. The final 'brief' should be a synthesis of top-down, middle-up down and bottom-up requirements, which divides the interests and physical shells in a well-balanced manner by the separate design processes. By separating the design interests and physical building shells as well, the subjective influences of all stakeholders can also be considered.

6.3. Second outcome: development of and reflection on instruments and guidelines

The theoretical framework delivers diagnostic instruments at four levels: (1) one general, and three specific levels of (2) people, (3) planet and (4) possibilities.

1. General: The objective of the first step, the first and general level, in this study was to develop an instrument to diagnose the causes of the problems in a systematic manner. This initial step of the system analysis aimed to deliver a format for needs-centred guidelines (NCGs) for primary schools, which take into account the influences of stakeholders' subjective behavioural patterns during decision-making (chapter 2). The next sections contain three sequentially related sub-studies of different interest scales, such as those presented in the multi-level scaled 6P balanced model by the opportunity axes (system stability): end-user/societal/educational interests (people), sustainable development interests (planet) and school building design and process interests (possibilities).
2. People: The objective of the second step, on the second and more specific level, was to achieve an architectural synthesis from the preliminary theoretical framework by introducing a step-by-step plan to distinguish the different interest within this social/educational continuum of interests in particular. This step-by-step plan focused on primary school building end-users to provide a better balance between societal, generic end-users' and individual end-users' needs. As a result of this analysis, an

internal system balance was achieved by introducing the social fractal and developing the guidelines for primary school building design: the needs-centred guidelines for schools (chapter 3).

3. Planet: The objective of the third step, on the second and more specific level, was to integrate the results of the micro end-user scale of interests with the social macro-environmental interests, and with its physical school building relationships. As a result, an internal system stability was achieved by introducing the sustainable development fractal that connects social systems and ecosystems, and within it school building design morphological factors, to balance the integrated physical built environment scales. The recognition of self-similarity factors, referred to as entities, that the different social system and ecosystem scales have in common also distinguished the physical scales relationship of spaces and places. Within this, the social dimension of intra- and intersubjective and intra- and inter-objective interests were identifiable and design scales impacts could be weighted qualitatively and quantitively. This step ultimately led to the generation of the sustainability-centred guidelines for schools (SCGs) (chapter 4).
4. Possibilities: The objective of the fourth step, on the second and more specific level, the third specific instrument, was to study the consequences, outlined in chapters 2, 3 and 4, for the AEC industry. This led to the generation of a third system instrument to balance the internal system interests, whilst also considering external meta-system influences. The further developed theoretical framework recognizes this whole picture of interests and influences in school building design and defines a stable set of entities to frame the decision-making processes. The process can be balanced better by team settings which take into account the integration of multiple subjective and objective levels, as formulated in the process-centred guidelines for schools (PCGs) (chapter 5).

These four diagnostic instruments integrate the different systems at multiple levels and connect the subjective and objective scales of interests by top-down, middle-up down and bottom-up perspectives. This allows a better balance to be achieved within primary school building design as a whole by its related qualitative and quantitative scales of the recognized polar self-similarity patterns of entities. For example, the first diagnostic instrument (chapter 2) and the final diagnostic instrument (chapter 5) integrate and connect fully; on the one hand, the instruments developed recognize and increase the awareness of non-rational behaviour during decision-making, and on the other, the instruments avoid non-rational behaviour during decision-making by separating the top-down, middle-up down and bottom-up approaches. The guidelines ultimately led to a guide that translates the theoretical framework into a more accessible guide for practical application. Appendix A gives an overview of the guidelines extracted from chapters 3, 4 and 5.

6.4. Validation process

<u>Theoretical framework:</u> Within a change agency setting, external participants attended regular meetings to discuss the theoretical research outcomes (chapter 5). Psychologists, architects and advisors from the construction industry and the government have been involved since 2015 to support and validate the presented needs-centred theory. In particular, psychologists understood the extent of the social fractal mechanism of human needs that was developed. Other stakeholders needed more time to understand the theory. The

framework was presented and discussed monthly in expert groups from different disciplines, for example, psychology, real-estate, architecture, environmental sciences and education. Once the group became too big, the change agency group setting needed to be reduced to a maximum of 10 stakeholders. In February 2015, the group was subdivided into three smaller groups: the bottom-up, middle-up down and top-down interest groups. From that time on, stakeholders became increasingly aware of the extent of this system approach. Members and students were experimenting with the extent of the human needs fractal and other related methods (e.g. intrinsic motivation relationship). Questionnaires and tests were used to investigate participants' own picture of positions in decision-making (chapter 5). Autonomous and heteronomous influences, as well as subjective and objective interests and polarity thinking, intrigued the stakeholders in the top-down, middle-up down and bottom-up groups. Furthermore, other schools became involved to experiment with this new transition method. A leading external transition company also became involved to discover the value by comparing it with other methods, such as 'Empowerment', which combines motivational factors and needs.
Application in practice showed that it is not necessary to explain the background of the theoretical framework to every stakeholder; this might even turn out to be counterproductive. The method just needs to be to made more accessible by reducing the complexity, which can be achieved by initially working with just the six entities and their polarities.

<ins>Instruments and guidelines:</ins> Although the instruments and guidelines still need to be tested in practice, students and stakeholders are already involved with this subject-related study by writing their thesis using the diagnostic instruments developed. Stakeholders involved in the change agency remain interested in collaborating and in finding out how to use the theory presented for the benefit of their company or for the government (see also chapter 5). New stakeholders are also involved, for example, a construction management company is comparing the needs-centred approach of divided 'brief' processes that was presented with regular design approaches.
A prototype of an energy-neutral Dome school is being designed based on the six entities programme of requirements. This programme will also be tested by all stakeholders involved to validate the entity values on multiple levels. From an end-user, a middle-up down and a bottom-up perspective, students (in this case not school pupils) and stakeholders develop the programme of requirements. For example, entity 1 relates to the need for certainty, to environmental factors and to functionality factors at the scale of the Dome base-building structure of the shell. This relates to the biosphere of the Dome, to letting food grow, to creating open natural learning environments and to the mutual scales of ecological classrooms, furniture etc. Using the research instruments presented, all entities will establish a programme of requirements dovetailed to each other's requirements and on a hierarchical level of scales. The different types of rooms, including classrooms, will be situated within this Dome, for example a plug 'n play high tech classroom, a classroom that can be disassembled and therefore changed and an ecologically biobased built room. This plan to build a school started at the Energy Transition Centre 'EnTranCe' innovation lab for education and research as part of the sustainable buildings theme. The school will be realized on the site of the university campus in Groningen.

The first practical lessons taught us that it is not desirable to explain the background of the instruments and guidelines comprehensively to every stakeholder. They just need to be made simpler and more accessible by reducing the complexity. This can be achieved through using the six entities and their polarities to understand the mechanism. Students have already illustrated that this method works.

6.5. General recommendations

It is obviously difficult for most stakeholders to, on the one hand, understand the entire system complexity, whilst on the other hand, the current system is being made more complex. The persistent problems are becoming extremely complex to solve without understanding their underlying mechanisms. The first recommendation is therefore to reduce the complexity by focusing on the polarities, with an emphasis on the top-down stable entities of environmental, legal and sociological factors (opportunities) instead of on current economic, political and technology-dominated factors (probabilities), and to use the social fractal to recognize end-users' and stakeholders' behavioural patterns and human needs relationships. Different interests can easily be separated into a top-down and a bottom-up interest approach, with decision-making at the centre representing the middle-up down interests. As a new starting point to establishing a more balanced programme of requirements that is better attuned to Dutch primary school building design, the newly developed instruments and guidelines can be a helpful addition that can be used to balance these interests more precisely on multiple levels and to address the different responsibilities. Respecting the different interests is a natural way of dividing the relevant spaces/places of interior (end-users), exterior (local community) and operational/maintenance interests (school management boards). It is therefore recommended to avoid dialogues and consensus in decision-making as much as possible, which differs hugely from regular design methods, even when a user-centred design approach is meant to be used.

The second recommendation is to educate new professionals by means of a broad and interdisciplinary training programme. This also means that new teaching curricula must be introduced in the domain of the built environment. Based on this perspective, architectural design studies should be partly replaced by studies such as integrated product design, which also incorporate discovery stages to initiate innovations from an end-user's point of view. It is not expected that the current system of conditioned and conventional patterns will change any time soon, which means that new generations must still challenge the AEC industry with new ideas for innovation. Although new school building design might be better because of the assembly of modular systems for its exterior and interior, arts and architectural design remain significant factors in design. To manage the processes as described, environmental and social sciences should be integrated into new curricula to balance the subjective and objective influences. Newly educated professionals can overlap the different domain interests to prevent current imbalances and non-rational behaviour in processes (chapter 5).

The third recommendation is to increase the awareness of current stakeholders' subjective behaviour patterns by acquiring more knowledge of human needs, emotions and the impact of rational and non-rational behaviour to improve the physical school building design quality. Emotions are the major driver for change, which obviously should play a role in realizing true innovations and transitions in the current conditioned and conventional AEC industry. This is true for primary school building in particular. To convince the stakeholders involved, it is therefore recommended to show them an attractive prototype of a new primary school building (the pleasurable way), instead of increasing attention by pointing, for example, toward the hidden impacts of environmental costs and correcting the system this way (the painful way). This new heuristic design, inspired by positive psychology, can change the system in a positive way.

The final recommendation is that the middle-up down-related stakeholders involved, and the AEC industry in particular, should respect the separated interests and adhere to the development of Open Building Manufacturing by embracing base building exteriors for maximum flexibility; as top-down stakeholders' heteronomous interests and maximum autonomy by interior commodities and as infill industry for bottom-up stakeholders. This separation of top-down and bottom-up approaches opens up new opportunities that might trigger the supply chain infill industry and prefab off-site/base building industry to come up with new business ideas from within the prefabrication modular buildings industry. For example, plug 'n play learning environments and energy supply units can already be placed under a geodetic dome – a structure developed by Buckminster-Fuller – and is compatible with Open Building Manufacturing (Kazi, Hannus, & Boudjabeur 2009; Kendall & Teicher 2000).

6.6. General discussion and conclusion

Society appears to strive for prosperity through economic, political and technological changes. The underlying needs mechanism, offering different ways of fulfilment, seems to be underestimated. Our global ecosystem, however, does not provide endless renewable sources of elements and energy to succeed in creating a stable balance since it is restricted by the world's single ecosystem. This thesis shows, however, that due to the recognized similarities, every other system has the potential to balance the entire global system from a 'meta' point of view. However, the underlying patterns simply seem to not be understood well enough. Alternative fulfilment of individual and collective subjective and objective interests and a broad consideration of the underlying needs might therefore offer attractive solutions to reducing the complexity that we face today. The association between these interest scales and the physical scales of built environment necessitates more awareness of how we fulfil these needs in the current situation and how it affects society and end-users. The solution focuses in particular on the contribution of social psychological involvement and participation in construction-related school design processes.

This study offers a system analysis-based theoretical framework to improve the balance between scales and interests, such as in the case of Dutch primary school building design, with the development of instruments and guidelines. This theory is launched as a new heuristic design that includes a consistent recognition of multiple levels of self-similarity patterns. The recognition of these self-similarity patterns in intra- and intersubjective and intra- and inter-objective interests led to the identification of an imbalance of interests in school building. The theory, instruments and guidelines contribute to balancing all interests in a polar, mutual and hierarchical manner, both quantitatively and qualitatively. The imbalances were recognized as the main cause of the physical problems stated. The theory developed offers new insights by using this polarity-based thinking method to further illustrate why current methods to improve school building fail. A systems thinking-based method makes it possible to relate the different interest scales to the physical learning environmental scales. From a 'meta' point of view, six entities balance the individual intra- and intersubjective needs and collective intra- and inter-objective interest relationships with, for example, the sustainable, flexible, adaptive, financial, political and technological agenda of school building design. The individual intra- and intersubjective levels of human needs relationship with the collective intra- and inter-objective interests seems to be both objective in nature and universal, considering that needs constitute the necessary requirements when using these levels of scaled interests. The system analysis only shows current imbalances and how they lead to drivers for change by focusing on six factors, their polarities and their multiple levels of self-similarity patterns association. When considering these six factors of self-similarity from a sustainable development perspective, this thesis offers new holistic insights with which the understanding of the 6P model developed can help to achieve autonomous and heteronomous system stability. Considering the non-rational behavioural patterns in decision-making processes that include human needs-based factors and that determine the design quality criteria for end-users and rational school building design and constructions, this way of reasoning offers a continuum that balances all subjective and objective interests scales holistically. When using this polarity thinking method of coherent mutual and hierarchical relationships on multiple levels, a unified method might generate new insights. There might, however, also be other underlying reasons as to why the world is obsessed by growth; reasons that cannot be understood. '*Some problems are so complex that you have to be highly intelligent and well informed just to be undecided about them*' (Laurence J. Peter).

The research-question '*how to improve Dutch sustainable primary school building design from an integrated perspective of interests*' was answered by creating a new theoretical framework to understand the problem complexity. To unravel its complexity, a system analysis led to a subsystem-based approach that separated and integrated the different interests at multiple levels to balance the design from a new self-similarity fractal-based perspective. The synthesis of these elements generated a new theoretical balance, the outcomes of which have been translated into several guidelines and instruments for practical application. Taken together, this justifies further exploration of Open Building methods.

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Appendix A: Guidelines

No.	Guidelines
	Needs-centred guidelines (NCGs) (see chapter 3)
1	Consider the scope of the four principles of human needs relationships: (1) physical environmental shells; (2) end-users' psychological, physiological and biophysical interests; (3) the dynamic mechanism and ratio balance and (4) the needs paradoxes.
2	Separate the end-user's needs from the societal needs within the [1st] continuum. Be aware of their different perspectives and possible conflicts with other interests (e.g. institutional or process actors) within this continuum.
3	Separate the individual's needs from the end-user's needs within the [2nd] continuum. Be aware of different individual perspectives and possible conflicts with someone else's perspectives and with other end-user interests. For example, different end-user interests could be caused by gender and age differences and different personal characteristics.
4	Relate end-users' heteronomous interests to the adjusted heterogeneous physical learning environment within the [3rd] continuum. Be aware of the societal interests influencing end-users as well as building performances. Use the four-polarity balance as a central point of approach to define the physical learning environmental shells within the paradoxical relationship pattern of down- and upward and in- and outwards-directed human needs, whilst considering the biophysical, physiological and psychological time-related influences.
5	Relate individual end-users' autonomous interests to the adjusted personal physical learning environment within the [4th] continuum. Be aware of personal interests influencing end-users as well as building performances. Use the three personal characteristics of time, sensory stimulation and place as a specific approach that define the individual to adjust to physical learning environmental shells, within the paradoxical relationship pattern of down- and upward and in- and outwards-directed human needs.
	Sustainability-centred guidelines (SCGs) (see chapter 4)
6	Consider the different end-users' and societal physical learning shell perspectives of intra- and intersubjective experiences by human needs (spaces) and intra- and inter-objective factors of sustainability requirements (places) within the dynamic of the conditional circumstances and characteristics, such as polarities, resilience, time/stages and the ratios required to find a balance, and to relate them to adjusted discipline domains.
7	Consider the pattern similarity entity to balance 40% of the value for certainty and environmental influences and to establish the 40% functional specifications for functionality in the brief and during the design iteration stages for multi-level building structure.
8	Consider the pattern similarity entity to balance 25% of the value for variation and legality influences and to establish the 25% functional specifications for aesthetical and creative specifications in the brief and during the design iteration stages for multi-level building flexibility.

9	Consider the pattern similarity entity to balance 15% of the value for connection and sociological-cultural identity influences and to establish the 15% functional specifications for social specification in the brief and during the design iteration stages for multi-level building association..
10	Consider the pattern similarity entity to balance 10% of the value for significance and economic influences and to establish the 10% for financial specifications in the brief and during the design iteration stages for multi-level building singularity.
11	Consider the pattern similarity entity to balance 6% of the value for contribution and political influences and to establish the 6% for durable specifications in the brief and during the design iteration stages for multi-level building adaptability.
12	Consider the pattern similarity entity to balance 4% of the value for growth and technological adjustments and to establish the 4% for extension specifications in the brief and during the design iteration stages for multi-level building expandability.
	Process-centred guidelines (PCGs) (see chapter 5)
13	Start with collecting the necessary information from the bottom-up side (end-user) and the top-down (local community) part of the assignment. Also collect information from the fit-out industry components and modular constructions that work according to Open Building principles.
14	Arrange a team that is put together according to the polarity pattern entities. Consider everyone's position and individual profile in relation to needs fulfilment (an education expert, a coach, an AEC advisor, a management board member, a politician and a sustainability expert).
15	Consider the underlying patterns in order to understand the complexity resulting from incomplete knowledge, the contradictory interests and continuous change that demands a design that facilitates this change.
16	Establish a concept programme of requirements that is adjusted to the theoretical polarity patterns framework principles (AEC advisor). In addition, sort the intra- and intersubjective comments in order to make underlying patterns in the process of establishing the requirements phase explicit (coach). This will allow the quality of decision-making to improve.
17	After establishing the programme of requirements, the design phase can start by establishing a project team made up of AEC members (architect, contractor, coach, advisor, board member and LCA expert). The design should be based on polarity patterns and anticipate future changes. It should remain clear that there is no such thing as a static programme for a building. Reality makes the programme dynamic, which can hopefully be incorporated into the layers of changing physical shells that create places (e.g. modules, components, elements and materials) and subsequently spaces (e.g. experiences).
18	Consider the four fragmented polarity patterns that help to facilitate the materialization of the educational vision of the school board.

SUMMARY

Dutch primary school buildings represent the daily social and physical environment for many end-users, including some of the most vulnerable end-users: pupils. The thesis presented considers the physical learning environment problems society is facing today. These seem to be very complex and difficult to solve because of the different interests involved. The current system leads to imbalances and fragmentation that increase the complexity of the design challenge without reducing its physical problems. Pupils, teachers and educationists (the end-users) are mainly focused on the social, educational and pedagogical processes. School management boards are concerned with operational and maintenance costs, whilst municipalities are concerned with new school building investments and local community interests. Different ministries are responsible for education, school building construction and energy reduction policy and legislation. Split incentives and different interests lead to imbalanced design perspectives, as well as to fragmented approaches by and responsibilities of Architectural, Engineering and Construction (AEC) industry stakeholders. Taken together, this leads to poorly performing primary school buildings that affect various interested parties. End-users, for example, are faced with poor indoor climate quality and layout functionality problems, school management boards are faced with unexpected construction and maintenance failures and society with a disappointing sustainability performance. Poorly understood requirements and a rather conventional AEC process make it difficult for designers to realize adequate and sustainable primary school buildings.

The approach to designing learning environments is generally a top-down process and is considered from a one-size-fits-all perspective. It consequently does not meet end-users' needs and lacks a genuine sustainable approach, an effective process and the flexibility to adapt to future changes. Designers of school buildings never changed their designs of learning environments or approached them critically. Many construction materials cannot be considered sustainable from a circular approach. Current school building designs, the materials used and the energy use are not sustainable. School buildings also fail in terms of the building's lifetime because of their short period of functionality and usability, whilst from a technical point the school building's main structure and components can last a very long time. School buildings are not well balanced from a functional, economic and technical point. Technically the buildings can be used for decades, whilst functionally they are obstructing the educational process much earlier. For example, the recently built multifunctional school accommodations (MFAs), influenced by political housing policy, never lead to the expected educational value and improvements of the indoor climate quality. Newly built schools, often part of multifunctional accommodations, generally do not even perform better than the old school buildings. Currently, after so many new MFAs have been built, smaller integrated child centres in particular are preferred from an educational, operational and management perspective. Whether such new buildings increase added value remains unclear. Several studies do not demonstrate any added value for the children's development,

where added value is defined as achieving higher scores in cognitive and social-emotional domains. Non rational behaviour of stakeholders affects the decision-making process in teams made up of collaborating parties. Stakeholders generally do not have the specific knowledge to deal with the increasing design complexity and have a poor understanding of the requirements of the design assignment. The use of technical systems, such as Building Information Modelling and contract process leading systems, such as Systems Engineering, indicates an increasing need for the integration of more systems thinking-based methods for new school building design to reduce the design and construction failures. But as long as the physical environmental requirements are unknown and not well understood, it might not come as a surprise that current design processes cannot combine everyone's interests by only looking at architectural issues to come to a consensus and that failures must be accepted. The current school building system shows many shortcomings and satisfying solutions seem to be difficult to achieve whilst striving for a more balanced system of multilevel interests and integration of the interests of different collaborating stakeholders. Obviously, there are more questions than answers. An analysis of the problems generates a bigger picture of the whole situation by considering end-users, management boards and society, and their relation with sustainable development, which subsequently also affects the AEC industry processes. The research question is: *how to improve Dutch primary school building design from an integrated perspective of interests?*

The problem analysis reveals a glimpse of the impact of hidden and unsuspected underlying social system-related human factors that add to the complexity. Systems thinking is used to analyse the problems by developing a model that incorporates the multilevel social human needs; from individual end-user to society and from government to AEC industry. Individual subjective interests (e.g. behaviour) interrelate with collective intersubjective interests (e.g. culture, identity) and also with individual objective interests (e.g. biological) and collective inter-objective interests (e.g. sustainable development). A continuum of stakeholders makes up a system comprising several main groups of individual and generic end-users, school management boards, local communities and society. The analysis is directed by government legislation and municipal policy, AEC industry and business stakeholders and specific disciplines that contribute to end-users' interests in particular, such as medical health services and sensor and IT techniques to control the indoor climate quality. The model relates the needs and interests to the physical environment of the school building, which is dictated by the neighbourhood, school environment, exterior (e.g. facades), interior layout, classrooms and other rooms, and furniture. This breakdown of interests and physical environment is necessary to understand the complexity of the system and requires the underlying system patterns to be considered to relate them to the causes of the problems and the effects achieved using current physical design approaches. Therefore, the system includes a polarity thinking approach and a related social-psychological analysis of six hierarchical (strive for growth) and mutual (strive for balance between autonomous and heteronomous interests) human needs, inspired by the positive psychology.

An integrated model has been developed that should lead to a stable balanced system. It is based on three dimensions: People-Planet-Process dimensions. These dimensions are the factors that connect known problem causes and effects, and to do so, use three multilevel domains: psychological, physiological, and biological/ecological factors. This three-axes model of needs, material school building and the lifetime of buildings, and its design process actors identify the different, often paradoxical or antagonistic, interests using a twofold system perspective from a macro (e.g. society) and a micro (e.g. end-users) approach, coming together at the meso-positioned stakeholders (e.g. municipal officials or school board members). The development of this theoretical framework subsequently incorporates a unified 'social fractal' of human needs that seems to be strongly related to all identified problems. Besides the generic influence of these needs, more awareness of stakeholder behaviour patterns can be obtained by understanding the influences of stakeholders' own human needs fulfilment patterns. The model provides a better understanding of the intra- and intersubjective, and intra-and inter-objective requirements, of how the unified multilevel needs relate to the physical learning environment as well as to the behaviour of all stakeholders involved, and how imbalances cause physical building problems. This systemic approach allows a first step to be made towards the creation of a theoretical framework that is based on human needs and that recognizes a relationship with the dynamics of a complex adaptive system that is based on mutual and hierarchical polarities. The resulting generic framework is one of Needs-Centred Guidelines (NCG). The system analysis, the three-axes model and the steps of the theoretical framework were subsequently used to study the three axes described: one-by-one and from a cumulative perspective of People-Planet-Process (see Chapter 2).

The first axis of the People-Planet-Process model focuses on the dimension of People (needs) whilst the comprehensive system analysis of the Needs-Centred Guidelines framework (NCG) generates a new perspective on and instruments for the establishment of end-users' requirements from a human needs perspective using the Needs-Centred Guidelines for schools (NCGs). The human needs are generally known as core needs for food, cloths, shelter et cetera, but in this thesis the needs are described as social needs for certainty, variety, social connection, significance, contribution and growth. A continuum of these social needs comprises a variety of interests: end-users' generic needs, end-users' individual needs and societal needs. End-users' needs differ between individuals and physical environments should be adjusted to their personal needs (e.g. the psychological need for certainty or variety and the different physiological needs for warmth). An important result is the recognition of the value of underlying patterns when considering autonomous and heteronomous polarities and the recognition of how mutual social and physical needs are inseparably interrelated (individuals with their peer groups, et cetera). A step-by-step method has been developed as a set of directions that focus primarily on the demands of end-users, for example, in an attempt to objectify and describe their intra- and intersubjective experiences from a human needs approach of the required physical learning environments that also considers individual differences. For this method a 'social fractal' of the six human needs, and within it the polarity mechanism, was used to generate qualitative and quantitative indicators. To meet the generic and individual end-users' needs, new insights were obtained that connect heteronomous and autonomous interests from a social and physical environment (see Chapter 3).

The second axis of the model concerns the dimension of Planet (the lifetime of school buildings and building construction elements). The sustainability-oriented guidelines for the design of Dutch primary school buildings were derived from a system analysis considering the integration of social systems and ecosystems. The observed integration balances the human needs with the interests of sustainable development, which includes the sustainability of school buildings. By means of theoretical reasoning, arguments are given to demonstrate that the six sustainable development factors show a narrow associative similarity pattern with six human needs factors. The sustainable development factors are generally known as PESTEL factors: political, economic, sociological, technological, environmental and legal. The recognition of stable and unstable polarity patterns from a hierarchical perspective and the autonomous and heteronomous polarity patterns from a mutual perspective lead to a 'sustainable development fractal' that connects the social systems to the sustainable development system, referred to as self-similarity patterns. The next step in the development of a theoretical framework relates materials, including renewable materials, and energy resources to the need for certainty (e.g. preferences for natural materials, biophilic design and the use of locally produced bio-based materials). By extending this reasoning method to associative similarity patterns, a connection was identified between the six sections of regular requirements programmes that also demonstrated this self-similar pattern in commonly used sections of a brief and an identifiable relationship with the morphological design of school building, including all its physical learning environment layers. These entities of self-similarity patterns provide a new transition interpretation to realize a more balanced bigger picture than offered by current methods. With this theoretical framework the Sustainability-Centred Guidelines for primary schools (SCGs) and instruments are being developed for application in practice (see Chapter 4).

The third axis of the model concerns the Process dimension, which can be combined with the People and Planet axes to achieve a final state of balance. However, the complexity caused by the troublesome effects of uncertain influences, rapid changes, including unknown and unsuspected changes, relate to the system interests and physical design. The self-similarity pattern of associated factors also identified a 'process fractal' in addition to the social and the sustainable development fractals. In this way, the elaboration of the theoretical framework lead to an integration of three fractals, which was used to establish a balanced school building design. To merge them all, a top-down and a bottom-up perspective of interests was used, as well as a middle-up down interests perspective. The separated physical learning environment layers relate to these different perspectives of interests. It also indicates a new setup of process teams from these top-down and bottom-up perspectives to deliver the requirements from intra- and intersubjective and intra- and inter-objective perspectives. New discipline arrangements should be incorporated from social sciences (e.g. psychology, sociology, pedagogy), natural sciences (e.g. environmental sciences), policy, politics and technical sciences (e.g. sensor technology, ICT, integrated product design). In addition to a rational intra- and inter-objective position in the discipline arrangement, defining the new types of participants in design teams also needs an assessment of stakeholders' own subjective psychological suitability to fit the role within the team at that moment. This can be seen as a form of integration of the fractals . It facilitates a more balanced collaboration between different disciplines, corresponding with the six associated factors or entities. A relationship between the instrument and increased stakeholders' awareness was identified (see Chapter 2). The influence of individual stakeholders in decision-making processes has also been recognized, which closes the circle of the multilevel three-axes model of this research.

On the one hand, this system offers end-users more freedom to integrate more autonomously the supply chain products from 'infill industry' (consumers market products) into the interior physical layers (e.g. plug 'n play classrooms), whilst on the other hand, it offers scope for increasing involvement of society, for example the local communities, which generates room for harmonization of the different interests in the exterior-oriented physical layers (e.g. identity, culture). The AEC industry's focus should shift toward prefabrication, such as the Open Building method. This raises new questions, for example, how to combine the load-bearing structure and facades with interiors that are flexible and that can be adjusted to future changes. The answer lead to the integration of the load-bearing construction into the facade and/or roof (e.g. see Dome buildings). In this way, the separate physical learning environment layers balance as predicted by the People-Planet-Process axes. However, due to rapid global changes, unknown and unsuspected, the whole school building system is influenced by a dynamic range of external influences. For example, in addition to the rather predictable demographic changes, humanity faces rapid technological, political and economic changes. A connected relationship was found by applying the Panarchy theory, which outlines the multiple levels of systems and the internal and external influences on the system. Consequently, the preliminary three axes model evolved towards a six axes model that takes into account additional system boundaries and polarities to offer a dynamic and balanced school building design. The Process-Centred Guidelines for primary schools were developed to consider these approaches in order to implement them in practice (see Chapter 5).

This system analysis contributed to the establishment of a theoretical framework and instruments for practical application, such as the guidelines, to come to a better understanding of Dutch primary school building design problems and their complexity. The synthesis replaces the preliminary People-Planet-Process model with a more robust and stable People-Planet-Possibilities model that also offers the opportunity to adapt to unstable factors, whilst it attempts to complete a six axes 'P' model by adding the Particularities-Potentials-Proliferations dimensions. These dimensions, presented as entities, exhibit a self-similarity fractal-based pattern of polarities through a relationship between autonomous/heteronomous and hierarchically related stable/unstable recognizable system characteristics. That is important to know, not only to balance the factors qualitatively, but also to balance them quantitatively. The gap between end-users and societal processes encourages the balancing of the interests of the continuum of end-users, school boards and society; the impact from autonomous and heteronomous influences, individually and collectively and subjectively and objectively. In this way, human factors can be integrated into the technically and financially dominated AEC industry. Existing thinking and belief patterns of every individual stakeholder should therefore be considered from positive psychology-based approaches to avoid non-rational behaviour in the decision-making processes. The general synthesis allows a distinction to be made between the infill industry interior (e.g. plug 'n play modules), which mainly concerns the bottom-up interests of end-users (e.g. furniture, classrooms and equipment), and the base-building construction industry of the school building exterior (e.g. load-bearing structures, facades, floors and roofs), which relates to the top-down interests. From this point of view, Open Building should be adopted more often than is currently the case. The research question '*how to improve Dutch sustainable primary school building design from an integrated perspective of interests*' has been answered by creating a new theoretical framework to understand the complexity of the problem. To unravel its complexity, a system analysis lead to separate subsystems that integrate the different interests on a multilevel scale and balance the design interests from a fractal-based perspective of unified self-similarity patterns. The synthesis generates a new method for defining the theoretical subjective and objective requirements of all stakeholders and translate these into a number of instruments and guidelines for practical application (see Chapter 6).

SAMENVATTING

De Nederlandse basisschoolgebouwen vertegenwoordigen de dagelijkse behoefte aan onderwijshuisvesting vanuit zowel een sociaal als een fysiek perspectief op leeromgevingen voor eindgebruikers, waaronder een van de meest kwetsbare: de leerlingen. Het voorliggend proefschrift beschouwt de huidige fysieke problemen met leeromgevingen waarmee de samenleving vandaag de dag wordt geconfronteerd. Deze problemen lijken erg complex en moeilijk oplosbaar vanwege de vele verschillende belangen. Het huidige systeem leidt tot onevenwichtigheden en fragmentatie van belangen die de complexiteit van de ontwerpuitdaging verder vergroten zonder dat de fysieke problemen verminderen. Leerlingen, leraren en pedagogen etc. (in het kort de eindgebruikers), zijn zelf vooral gericht op de sociale, educatieve en pedagogische processen. Schoolbesturen houden zich daarnaast bezig met operationele en onderhoudskosten, terwijl gemeenten zich vooral bezighouden met het beleid dat als ‘sober en doelmatig’ bekend staat binnen het onderwijshuisvestingsbeleid. Investeringen in scholen worden vanuit als belangenvertegenwoordigers van de lokale gemeenschap door politiek gestuurd. Verschillende ministeries zijn betrokken en verantwoordelijk voor het onderwijs, de bouw van scholen, en voor beleid en wetgeving, zoals bijvoorbeeld energiebesparing. Verschillende uitdagingen en belangen leiden nu tot onevenwichtige perspectieven van wanneer een ontwerp van een school goed is, alsmede tot in standhouden van gefragmenteerde benaderingen van verantwoordelijke stakeholders binnen de bouw. Bij elkaar leidt dit tot slecht presterende schoolgebouwen voor de eindgebruiker hetgeen al deze verschillende betrokken stakeholders raakt. Diverse instituties in de bouw hebben onderzoek uitgevoerd, zoals de Bond van Nederlandse Architecten (BNA) naar deze slechte prestaties. Eindgebruikers worden daardoor bijvoorbeeld geconfronteerd met een slecht binnenklimaat en problemen met de functionele indeling, schoolbesturen worden geconfronteerd met onverwachte bouw- en onderhoudsproblemen, en de samenleving met teleurstellende duurzaamheidprestaties. Slecht begrepen wensen en eisen van eindgebruikers, en een nog altijd vrij conservatieve bouwsector, maken het moeilijk voor ontwerpers om adequate en duurzame huisvesting voor het primair onderwijs te realiseren.

De huidige benadering voor het ontwerpen van leeromgevingen is over het algemeen een top-down proces en wordt beschouwd als een one-size-fits-all benadering. Het voldoet dus per definitie niet gauw aan de verschillende behoeften vanuit een eindgebruikersperspectief en het ontbreekt bovendien aan een echt duurzame aanpak. Bijvoorbeeld een effectief proces zou flexibel en adaptief moeten zijn om zich aan te passen aan toekomstige veranderingen. Ontwerpers van schoolgebouwen hebben hun ontwerpen van leeromgevingen nooit veranderd of kritisch heroverwogen. Veel bouwmaterialen kunnen niet eens als echt duurzaam worden beschouwd vanuit een circulaire benadering. De huidige ontwerpen van schoolgebouwen zijn daarmee niet duurzaam gezien de toegepaste materialen en het energieverbruik in de bouwmaterialen zoals tijdens de

productie. Schoolgebouwen falen ook wat betreft de levensduur van het gebouw vanwege hun korte functionaliteit en bruikbaarheid, terwijl vanuit een technisch oogpunt de draagstructuur en constructieve componenten van het schoolgebouw juist heel lang meegaan. Schoolgebouwen zijn functioneel, economisch en technisch niet met elkaar in balans. Technisch gezien kunnen de gebouwen tientallen jaren worden gebruikt, terwijl ze functioneel al snel het primaire proces van onderwijs belemmeren. Zo hebben de recent gebouwde multifunctionele schoolaccommodaties (MFA's), beïnvloed door het politieke huisvestingsbeleid, niet geleid tot een bewezen maar wel verwachte educatieve meerwaarde, en tot verbeteringen van de kwaliteit van het binnenklimaat. Nieuw gebouwde scholen, vaak onderdeel van multifunctionele accommodaties, presteren in het algemeen vanuit het onderwijs gezien niet beter dan de oude schoolgebouwen. Momenteel hebben, pas nadat er zoveel nieuwe MFA's zijn gebouwd, vooral kleinere geïntegreerde kindercentra de voorkeur vanuit een educatief-, operationeel- en beheerperspectief. Of dergelijke nieuwe gebouwen wel een toegevoegde waarde hebben blijft echter nog steeds onduidelijk. Verschillende onderzoeken tonen namelijk geen enkele toegevoegde waarde aan voor de ontwikkeling van de kinderen, waarbij deze waarde dan wordt gedefinieerd als het behalen van hogere scores op cognitieve en sociaal-emotionele ontwikkelgebieden.

Ook is het niet rationeel gedrag van belanghebbenden van invloed op besluitvormingsprocessen binnen teams van samenwerkende partijen. De huidige stakeholders daarbinnen hebben over het algemeen niet de specifieke kennis in huis om met de toenemende ontwerpcomplexiteit om te gaan, en hebben onvoldoende begrip van onderwijs voor het goed uitvoeren van de ontwerpopdracht. Het gebruik van technische systemen, zoals Building Information Modeling (BIM) vormen op dit moment een nieuwe koers voor verbetering van de processen en van het opstellen van contracten. Ook de integratie van Systems Engineering wijst er op dat er een toenemende behoefte is aan meer op systeemdenken gerichte methoden voor het ontwerpen van nieuwe schoolgebouwen. Hiermee wordt geprobeerd het ontwerp te verbeteren en bouwfouten zoals die nog steeds veel voorkomen te reduceren. Maar zolang de eisen van de fysieke leeromgeving niet bekend zijn of niet goed worden begrepen, is het misschien ook geen verrassing dat de huidige ontwerpprocessen niet de belangen van iedereen kunnen vervullen door alleen door een architectonische bril te kijken en met consensus tussen de verschillende belanghebbenden de tekortkomingen, fouten en gebreken maar te accepteren. Het huidige scholenbouwsysteem vertoont veel tekortkomingen en bevredigende oplossingen lijken moeilijk te realiseren, terwijl wel gestreefd wordt naar een meer evenwichtiger systeem vanuit een multi-level perspectief en integratie van belangen van de verschillende samenwerkende partijen. Uiteraard zijn er meer vragen dan antwoorden. Een analyse van de problemen geeft een breder beeld van de hele situatie door meer rekening te houden met eindgebruikers, de schoolbesturen en de samenleving, en hun relatie met duurzame ontwikkeling, en de gevolgen voor de bouw en hun processen. De onderzoeksvraag luidt: *hoe kan het ontwerpen van Nederlandse basisscholen worden verbeterd vanuit een geïntegreerd perspectief van belangen?*

Een probleemanalyse geeft weer welke impact de verborgen en onbekende onderliggende aan het sociaal systeem gerelateerde menselijke factoren hebben bijdragen aan de complexiteit. Systeemdenken is gebruikt om de problemen met scholenbouw te analyseren door een model te ontwikkelen dat de sociale behoeften op meerdere niveaus weergeeft, zoals dat van individuele eindgebruikers en de lokale gemeenschap, of van overheid en de bouwkolom. Individuele subjectieve belangen (bijvoorbeeld gedrag) hangen samen met collectieve intersubjectieve belangen (bijvoorbeeld cultuur, identiteit), en ook met individuele objectieve belangen (bijvoorbeeld fysieke biologische eisen) en collectieve interobjectieve belangen (bijvoorbeeld duurzame ontwikkeling). Een continuüm van al deze belangen en hun clusters vormt een systeem dat bestaat uit verschillende groepen van individuele en generieke eindgebruikers, schoolbesturen, lokale gemeenschappen en samenleving.

De resultaten van de analyse geven weer dat het onderwijsdomein nu vooral wordt gedomineerd door overheidswetgeving en gemeentelijk beleid, de methodes binnen de bouwsector, en door andere zakelijke belanghebbenden. Specifieke disciplines die de behoeften van eindgebruiker zouden moeten dienen ontbreken, terwijl die juist zouden kunnen bijdragen. Bijvoorbeeld medische milieukunde (GGD) voor advisering over het binnenklimaat, of sensor/ICT technologie om de kwaliteit daarvan te beheersen. Het daarvoor ontwikkeld model relateert de behoeften en belangen aan een goede fysieke leeromgeving als schoolgebouw, die enerzijds wordt bepaald door de omgeving en de buurt waarin de school staat, zoals het exterieur van het gebouw (bijv. soort gevels), en anderzijds door de indeling en interieur van het gebouw, zoals de klaslokalen en andere onderwijsruimten, en meubilair. Door deze onderverdeling van belangen te koppelen aan de fysieke omgevingen is het beter mogelijk om de complexiteit van het systeem (proces) op deelgebieden te kunnen begrijpen. Het vereist daarbij een nadere analyse van onderliggende systeempatronen om ze vervolgens te kunnen relateren aan de oorzaken van het ontstaan van de problemen, en de effecten die worden veroorzaakt door de huidige ontwerpmethodes. Daarom is het systeem voorlopig gevat in een 3-assig model van People-Planet-Process dimensies, dat rekening houdt met de verschillende belangen en fysieke omgevingen vanuit een theoretisch kader. Door gebruik te maken van de sociale psychologie, vooral daarbij geïnspireerd door de positieve psychologie, blijkt binnen de behoeften een hiërarchisch patroon, en een wederzijds op autonome en heteronome gerichte belangen gericht patroon te bestaan. Daarmee kon een polaire relatie tussen de verschillende factoren worden geïdentificeerd.

De eerste as van het ontwikkelde People-Planet-Proces model betreft de dimensie People, waarbij de sociale behoeften centraal staan, en waarbij een uitgebreide systeemanalyse uiteindelijk leidt tot de zg. Needs-Centered Guidelines (NCG). Vanuit een nieuw perspectief op hoe behoeften en belangen kunnen worden benaderd is het mogelijk geworden instrumenten te ontwikkelen die eindgebruikers in hun eisen ondersteunen door zich te richten op meer balans tussen de menselijke behoeften. Vanuit dit perspectief zijn de richtlijnen voor scholenbouw (NCGs) ontwikkeld. De menselijke behoeften staan algemeen bekend als primaire behoeften voor voedsel, kleding, onderdak, enzovoort, maar in dit proefschrift worden de secundaire behoeften beschreven als: de behoefte aan zekerheid, variatie/spanning, sociale verbondenheid, zich onderscheiden, bijdragen en aan zich ontwikkelen. Een continuüm van deze sociale behoeften omvat een drietal gescheiden clusters van wederzijds aan elkaar verbonden belangen, t.w.: generieke behoeften van eindgebruikers, individuele behoeften van eindgebruikers, en maatschappelijke behoeften. Daarnaast verschillen de behoeften van individuele eindgebruikers onderling, en om aan de eisen van de individueel wenselijke fysieke omgeving te voldoen zouden de sociale- en fysieke omgevingsfactoren die de behoeften beïnvloeden op elkaar kunenn kunnen worden afgestemd. Bijvoorbeeld meer behoefte aan het beïnvloeden van het creëren van een veilige leeromgeving of juiste een uitdagende omgeving, of de behoefte aan het zelf kunnen beïnvloeden van de ruimtetemperatuur.

Een belangrijk resultaat is de herkenning van de waarde van onderliggende patronen bij het afwegen tussen de autonome en heteronome behoeften. Op hun beurt beïnvloeden deze, door hun wederzijds polaire relatie, elkaar ook weer, zoals binnen het continuüm van de verschillende groepen. Het begrijpen van hoe deze wederzijdse sociale en fysieke behoeften onlosmakelijk met elkaar verbonden zijn (individueel en tussen peergroepen, et cetera) en integraal samenwerken is essentieel. Een stapsgewijze methode is ontwikkeld waarmee primair gericht kan worden op de eisen van de generieke behoeften van eindgebruikers. Bijvoorbeeld in een poging om hun intra- en intersubjectieve ervaringen meer te objectiveren naast kwaliteitscriteria die zijn ontwikkeld (oa. RuimteOK). Het kunnen relateren van de menselijke behoeften aan de eisen gesteld aan een goede fysieke leeromgeving, kan ook gelden voor individuele behoeften, al kunnen deze verschillen per persoon groot zijn. Voor deze methode werd een z.g. ‘social fractal’ van zes menselijke behoeften ontwikkeld, met daarin een polariteitsmechanisme dat hier als hypothese is gebruikt om de kwalitatieve waarde van de behoeften (de genoemde behoeften als factoren) ook een kwantitatieve waarde te kunnen meegeven. Om aan de behoeften van generieke en individuele eindgebruikers te voldoen, zijn nieuwe inzichten verkregen die de heteronome en autonome belangen van sociale- en fysieke leeromgevingen met elkaar verbinden (zie hoofdstuk 3).

De tweede as van het model betreft de dimensie Planet, waarbij de duurzaamheid en levensduur van schoolgebouwen, en bouwmaterialen/bouwelementen voor het ontwerpen van schoolgebouwen centraal staan. De ontwikkelde op duurzaamheid gerichte richtlijnen voor het ontwerpen van Nederlandse basisscholen zijn afgeleid van de eerder genoemde systeemanalyse, waarbij de integratie van het sociale systeem (1^{e} as van het model) en het geanalyseerde ecosysteem hier nader is beschouwd. De waargenomen associaties tussen beide systemen maakt een integratieve relatie mogelijk, en vanuit deze wijze van redeneren kan het menselijke behoeften in evenwicht brengen met maatschappelijke belangen van duurzame ontwikkeling, in het bijzonder hier de duurzaamheid van schoolgebouwen. Door middel van een theoretische beschouwing worden argumenten beschreven hoe zes duurzame ontwikkelingsfactoren, zoals gebruikt binnen duurzame ontwikkeling, een nauw associatief gelijkenispatroon tonen met de zes factoren gebruikt binnen menselijke behoeften theorieën. De factoren voor duurzame ontwikkeling staan algemeen bekend als PESTEL-factoren: politiek, economisch, sociologisch, technologisch, ecologisch en juridisch. De herkenning van stabiele (robuuste) en onstabiele (dynamische) subsystemen binnen het gehele systeem, waarbij polaire patronen tussen de factoren en clusters van factoren voorkomen, leidt vanuit deze patronen tot herkenning van een onderliggende z.g. ‘fractal voor duurzame ontwikkeling’. Hiermee kan het sociale systeem associatief als fractal worden verbonden aan het systeem voor duurzame ontwikkeling. Daarmee wordt het begrip multi-level schaalniveau geïntroduceerd, dat naast de verschillende schalen van belangenclusters ook schaalniveaus van subjectieve en objectieve clusters herkent. In een volgende stap in de ontwikkeling van een theoretisch kader richting basisscholenbouw worden materialen en energiebronnen in relatie gebracht met de menselijke behoeften, zoals natuurlijke materialen met het gevoel van zekerheid. Door deze redeneermethode consistent door te zetten en de associatieve gelijkenispatronen verder uit te breiden is er een verband gevonden tussen niet alleen deze behoeften en duurzaamheidsfactoren, maar ook tussen zes regulier gebruikte hoofdstukken in programma's van eisen. Dezelfde redenatie geldt ook voor het herkennen van gelijkenispatronen binnen de morfologie van het ontwerp van schoolgebouwen, waaronder alle multi-level schaalniveaus van de fysieke leeromgevingen (van schoolmeubilair tot de omgeving van de school). Vanwege de gelijkenispatronen worden de factoren met deze gelijkenis vanwege hun eigenschappen entiteiten genoemd en bieden daarmee een nieuwe overgangsinterpretatie voor het realiseren van een meer evenwichtige en holistisch beeld dan huidige methoden kunnen bieden. Met dit theoretische kader zijn de op duurzaamheid gerichte richtlijnen voor basisscholen (SCGs) en instrumenten ontwikkeld voor toepassing in de praktijk (zie hoofdstuk 4).

De derde as van het oorspronkelijk People-Planet-Proces model betreft de dimensie Proces, die kon worden toegevoegd aan de assen People en Planet. De complexiteit van de problemen wordt mede veroorzaakt door de ingewikkelde multi-level geschaalde relaties en de verschillen tussen alle belangen binnen de bouw samenwerkende actoren, en door de effecten van een onzekere toekomst, zoals snelle nog niet in te schatten veranderingen. De gelijkenispatronen van de entiteiten (de tot elkaar associatief verbonden factoren uit de verschillende systemen) identificeren in dit hoofdstuk een 'procesfractal' die naast de andere fractals voor de sociale systemen en duurzame ontwikkeling systemen zijn ontwikkeld. Op deze manier leidt de uitwerking van het theoretische kader tot een integratie van op drie fractals gebaseerde associatieve systemen, die samen kunnen worden gebruikt een evenwichtig scholenbouwontwerp te realiseren. Om ze allemaal samen te voegen, dus als een synthese, is een top-down en een bottom-up perspectief van de belangen gebruikt, waarbij een middle up-down perspectief als een tussenschakel voor de definitieve besluitvorming in processen dient. De te onderscheiden schaalniveaus van de fysieke leeromgevingen hebben betrekking op deze verschillende perspectieven van interesses vanuit materialisatie en bouwmethodiek. Het stelt daarmee ook een nieuwe opzet voor van teams in ontwerpprocessen vanuit een top-down en een bottom-up perspectief om te voldoen aan de eisen, die als multi-level schaalniveaus kunnen worden onderverdeeld in intra- en intersubjectieve, en een intra- en interobjectieve perspectieven. Nieuwe disciplines zouden daarin moeten worden geïntegreerd vanuit sociale wetenschappen (oa. psychologie, sociologie, pedagogiek), natuurwetenschappen (oa. milieuwetenschappen), beleid, politiek en technische wetenschappen (oa. sensortechnologie, ICT, geïntegreerd productontwerp). Alhoewel huidige processen soms vergelijkbare benaderingen laten zien, zal naast een rationele intra- en interobjectieve positie van stakeholders bij de nieuwe discipline-indeling ook een reflectie op de persoonlijke subjectieve psychologische geschiktheid van stakeholders een rol spelen. Het definiëren van de nieuwe soorten stakeholders in ontwerpteams zal dus zowel vanuit de discipline als vanuit hun persoonlijke kenmerken op het moment van samenstellen van een team een rol spelen. Dit kan worden opgevat als een vorm van integratie van alle fractals. Deze hypothese kan een meer evenwichtige samenwerking tussen verschillende disciplines vereenvoudigen. Daarmee is er een fundamentele relatie gelegd tussen de ontwikkelde instrumenten om de invloed van behoeften van belanghebbenden in processen te identificeren. De invloed van individuele belanghebbenden in besluitvormingsprocessen wordt daarmee erkend, waardoor de cirkel van het drie-assig model met de drie multi-level schalen binnen dit onderzoek wordt gesloten.

Dit systeem zorgt ervoor dat eindgebruikers meer vrijheid krijgen, en de gehele inrichting en indeling meer als consumentenmarktproducten zouden kunnen worden benaderd, om over de producten uit de toeleveringssector ('infill industry') met meer autonome invloed te kunnen handelen over de condities van hun fysieke leeromgevingen in het schoolgebouw (bijv. een plug & play klaslokaal als module). Terwijl dit aan de andere kant van hetzelfde systeem ruimte biedt voor het vergroten van de betrokkenheid van de samenleving bij het schoolgebouw. Door bijvoorbeeld de lokale gemeenschap meer te betrekken doordat er ruimte gecreëerd wordt voor harmonisatie van de verschillende belangen en fysieke leeromgeving condities vanuit de buitenkant als perspectief (bijv. relatie identiteit, cultuur met de buurt). De focus van de bouwsector zou daarmee verder kunnen verschuiven van onsite naar offsite prefabricage overal waar mogelijk, zoals de Open Building methode betoogt. Dit roept nieuwe vragen op, zoals bijvoorbeeld hoe de dragende structuur en gevels kunnen worden gecombineerd met optimale flexibele interieurs die aanpasbaar zijn voor toekomstige veranderingen. Het antwoord leidt tot het uit elkaar houden van de dragende constructie door afdracht van krachten bijvoorbeeld volledig naar de buitenzijde te brengen (gevel en/of dak). Zoals bijvoorbeeld met zg. Domes als geodetische koepelvormige gebouwen waarbinnen een flexibele en adaptieve inrichting mogelijk is. Op deze manier zijn de afzonderlijke lagen van de fysieke leeromgeving als gescheiden clusters van belangen meer in balans te brengen, conform het eerder genoemd People-Planet-Process model. Als gevolg van snelle veranderingen, soms geheel onverwacht en onvoorspelbaar, lijkt scholenbouw steeds meer onder beïnvloed te staan door een dynamische invloed van externe factoren. Naast soms nog voorspelbare demografische sociologische verschuivingen, wordt men steeds meer geconfronteerd met snelle technologische, politieke en economische veranderingen. Een vermeende relatie werd de eerder al gevonden met de Panarchy-theorie (zie hoofdstuk 4) waarbij de verschillende systeemniveaus en interne en externe invloeden op deze systeem niveau kunnen worden beschouwen als niet lineaire veranderingen. Bijgevolg evolueerde het voorlopige model met de drie assen naar een model met zes assen dat rekening houdt met deze extra systeem beïnvloedende factoren en grenzen om de complexiteit te begrijpen en daarmee een evenwichtiger robuuster schoolgebouwontwerp te kunnen leveren. De procesgerichte richtlijnen voor basisscholen zijn ontwikkeld om deze benaderingen als overweging mee te nemen in de praktijk van de bouw (zie hoofdstuk 5).

De systeemanalyse heeft bijgedragen aan het opstellen van een theoretisch kader en levert instrumenten voor praktische toepassing, waarbij de richtlijnen een betere grip kunnen geven op het reduceren van de ontwerpproblemen en complexiteit van Nederlandse basisscholenbouw. De synthese van robuuste en dynamische systeem factoren vervangt uiteindelijk het voorlopige People-Planet-Process model door een meer stabiliserend model van People-Planet-Possibilities dat de mogelijkheid biedt om zich aan te passen aan de systeem beïnvloedende meer destabiliserende factoren. Deze dynamische destabiliserende factoren bestaan uit de drie assen genoemd Potentials, Proliferations, en Particularities, waarmee het zes-assig '6P' model nu uit zes dimensies bestaat. Deze dimensies, weer gepresenteerd als entiteiten, tonen op zichzelf opnieuw weer een fraktaal patroon van steeds herhalende gelijkenissen en de associatieve relaties met de ontwikkelde fractals. Het systeem als mechanisme is daarmee ook weer gebaseerd op de polariteiten met overeenkomstige relaties tussen autonome/heteronome en hiërarchisch gerelateerde stabiele/onstabiele systeemkenmerken. Dat blijkt belangrijk om te weten, niet alleen om de factoren kwalitatief in evenwicht te brengen, maar ook om ze kwantitatief een waarde te kunnen meegeven, al blijft het hypothetisch. De kloof tussen eindgebruikers en maatschappelijke processen kan worden overbrugd door evenwicht te bereiken tussen de belangen, als clusters uit het continuüm van eindgebruikers, schoolbesturen en de samenleving, waarbij de impact van autonome en heteronome invloeden, individueel en collectief, en subjectief en objectief meer specifiek wordt. Op deze manier kunnen menselijke factoren ook worden geïntegreerd in de door techniek en financiën gedomineerde bouwsector. Bestaande denk- en geloofspatronen van elke individuele stakeholder zouden daarmee kunnen worden onderworpen aan werkwijzen zoals gebruikt binnen de positieve psychologie om daarmee niet-rationele besluitvormingen in ontwerpprocessen te kunnen herkennen en wellicht voorkomen. De algemene synthese maakt het nu ook mogelijk om een onderscheid te maken tussen het interieur als 'infill'- industrie, voornamelijk gerelateerd aan bottom-up belangen van eindgebruikers (bijv. meubilair, klaslokalen en onderwijsvoorzieningen), en het exterieur als ruwbouwfase van de hoofdconstructie onderdelen voor het schoolgebouw (bijv. draagstructuur naar de buitenzijde brengen), die gerelateerd kunnen worden aan de belangen van buitenzijde van de school. Vanuit dit oogpunt zou 'Open Building' veelvuldiger kunnen worden toegepast dan nu het geval is. De onderzoeksvraag '*hoe kan het ontwerpen van Nederlandse basisscholen worden verbeterd vanuit een geïntegreerd perspectief van belangen?*' is beantwoord met het theoretisch ontwikkeld kader om vooral de complexiteit van de huidige problemen te begrijpen. Om de complexiteit ervan te kunnen ontrafelen, heeft een systeemanalyse tot afzonderlijke subsystemen geleid die de verschillende belangen op meerdere niveaus gebalanceerd kunnen laten integreren. De synthese genereert daarmee een nieuwe theoretische kader voor het definiëren van subjectieve en objectieve eisen van alle belanghebbenden en vertaalt deze in een aantal instrumenten en richtlijnen voor praktijktoepassing (zie hoofdstuk 6).

ABOUT THE AUTHOR

Ronald de Vrieze was born on February the 12th 1963 in Musselkanaal, a village in the former municipality of Onstwedde. He has obtained the bachelor degree in Building Construction at the former Rijkshogeschool Groningen. He started his career at architectural and engineering firms. During the period 1990–2006 he worked as a technical policy employee in building construction and environmental affairs, and later on he became head of the department building construction, civil engineering & greenery policy at a Dutch municipality in the Province of Drenthe. Since 2006 he is lecturer at the School for Architecture & Built Environment at the Hanze University of Applied Sciences of Groningen. After he attended education in positive psychology in 2008, he became inspired by the impact of the used coach methods, and wanted to study the interdisciplinary relationship between social and technical/environmental domains more deeply. Since 2009 he became a member at a research group in 'NoorderRuimte', the Research Centre for Built Environment, and since 2011 he coordinates the theme Sustainable Buildings at the Energy Transition Centre. He collaborates with external institutions, companies, scientists of social and natural science studies, and students in (school) building construction innovation programs. After a start-up period, he officially started his Ph.D. research in healthy sustainable primary schools in 2012. Since 2019 he became also lecturer at the International Master Energy for Society at the Hanze University.